When Less is More: School Schedule Reform and Student Outcomes

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Working Draft - Please Do Not Circulate

Abstract

We examine how school schedule reforms shape students' outcomes by studying the four-day school week, in which students attend school four rather than five days per week. We use comprehensive administrative data from Colorado, where this schedule is most prevalent in the United States. The dataset spans nearly two decades of entry cohorts and more than one million unique student records, providing us with a unique opportunity to study the policy's long-run effects. Leveraging quasi-random variation in adoption across districts in a difference-in-differences framework, we estimate how a shortened school week affects students' educational trajectories. In contrast to much of the existing literature, we find modest improvements in standardized test scores, lower dropout rates, and higher on-time and overall graduation rates. The duration of exposure plays a key role: students with longer and more consistent exposure experience the largest gains in persistence and attainment. Improvements in teacher retention and classroom expenditures also contribute to these gains. At the same time, heterogeneous effects indicate that disadvantaged students benefit less, raising concerns about equity. Overall, the findings suggest that a shorter school week need not necessarily harm student outcomes and can improve both performance and completion when designed and implemented carefully.

JEL Classification: H75 I21 I28
Keywords: four-day school week, student outcomes, teacher outcomes

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The authors are grateful to Michael Bates, Ozkan Eren, Delia Furtado, Joshua Goodman, Lehui Liu, Stephen L. Ross, Kevin Shih, and David Simon for valuable comments and suggestions. We also thank participants at the University of California, Riverside Applied Economics Seminar, the University of Connecticut Applied Micro Seminar, and the 2026 Chinese Economists Society North America Conference for helpful feedback. We especially thank Kathryn Wright, Data Sharing Manager at the Colorado Department of Education, and the staff of the Colorado Department of Education for their support with the data acquisition process. This paper uses confidential administrative student and teacher records from the Colorado Department of Education and was approved by the Institutional Review Board at the University of California, Riverside. The findings and conclusions are those of the authors and do not necessarily reflect the views of the Colorado Department of Education. Any remaining errors are the responsibility of the authors.

1. Introduction

Across the United States, the four day school week (4DSW) has emerged as one of the fastest growing educational reforms, reshaping classroom routines, family schedules, and teacher labor markets. Since 1999, the number of districts adopting this schedule has increased sixfold, reaching more than 850 districts across 24 states (National Conference of State Legislatures, 2023). Under this model, students attend school four days per week rather than five, with longer instructional days intended to preserve total instructional time. Proponents emphasize potential benefits such as cost savings, improved teacher morale, and greater flexibility for families, while critics argue that reducing the school week may harm learning and exacerbate inequality. The rapid diffusion of the 4DSW therefore raises a central policy question: how does this schedule affect student achievement, persistence, and completion, and under what conditions can students adjust without losses in learning?

Existing research on the 4DSW has focused primarily on elementary school students, with mixed findings. Several studies document declines in mathematics achievement following adoption, while effects on reading are less consistent (Thompson, 2021; Morton, 2023). Other work reports modest improvements in attendance but limited cost savings, largely driven by reductions in transportation and utilities expenditures (Ward, 2019; Morton, 2021). Fischer and Argyle (2018) further show that the 4DSW can increase juvenile property crime, particularly in urban and low income settings. Evidence on high school students remains comparatively scarce and is largely confined to two studies. Using data from Oregon, Thompson et al. (2022) find declines in test scores, lower on time graduation, and higher chronic absenteeism, while Morton (2023) reports modest reductions in disciplinary incidents in Oklahoma but no effects on ACT scores or attendance.

A common feature of much of this literature is its reliance on outcomes that can be measured shortly after policy adoption, particularly standardized test scores. Elementary achievement measures provide timely indicators of immediate academic responses and are therefore well suited for evaluating short run effects. However, a growing literature in economics shows that short run test score changes do not always translate into corresponding improvements in long run educational and economic outcomes (Chetty et al., 2014b; Dobbie and Fryer, 2020). Educational interventions may instead operate through persistence, engagement, school attachment, or other behavioral margins that emerge gradually over time and are not fully captured by contemporaneous test performance alone. This distinction is especially relevant in the context of schedule reforms, where students, teachers, and schools may require sustained exposure to adapt to changes in instructional organization and time allocation. In many existing settings, 4DSW adoption was relatively recent or short lived, limiting the ability to observe whether early academic responses persist, attenuate, or translate into meaningful differences in educational attainment. As a result, prior studies provide limited evidence on the long run consequences of the 4DSW for students' educational trajectories and human capital accumulation.

We therefore focus on high school students, for whom both the accumulation of policy exposure and the stakes of educational outcomes are especially pronounced. High school is the stage at which changes in school schedules are most likely to translate into durable and economically meaningful outcomes. While elementary and middle school achievement is important, these outcomes may be more responsive to later remediation and therefore may not fully capture whether schedule reforms alter long run educational attainment. By contrast, high school outcomes reflect discrete and often irreversible margins of human capital formation, including grade progression, dropout, and diploma completion. These margins directly shape access to postsecondary education, vocational training, and early career opportunities. A large literature further shows that high school completion strongly predicts lifetime earnings, labor market stability, health, criminal involvement, and intergenerational mobility, while non completion imposes persistent economic and social costs (Heckman, 2006; Lochner and Moretti, 2004; Oreopoulos and Salvanes, 2011; Chetty et al., 2017). High school students may also respond differently to schedule reforms because adolescents face substantially greater opportunity costs of time, including part time work, caregiving responsibilities, extracurricular commitments, and longer commutes. At the same time, high school instruction relies more heavily on subject specialization, course sequencing, and teacher continuity, rendering teacher labor supply, burnout, and retention particularly consequential. As a result, the effects of a shortened school week may operate less through immediate test score responses and more through persistence, engagement, attendance, and completion decisions that accumulate over time. Evaluating high school outcomes therefore provides a clearer assessment of whether the 4DSW generates lasting changes in human capital formation rather than short run academic fluctuations that may later fade out.

This paper makes four contributions to the literature on school scheduling, education policy, and human capital formation. First, we utilize comprehensive administrative data from Colorado that link the full population of public school students and teachers statewide from 2004 to 2023, comprising more than one million unique student records. To our knowledge, this is the first study to use Colorado's statewide longitudinal student data to examine the effects of the 4DSW, in a setting with the highest concentration and longest history of adoption in the United States. The combination of population-level coverage, cohort-level linkage from school entry through completion, and substantial variation in adoption timing allows us to study high school outcomes in a way that is not feasible in most prior settings.

Second, we provide new evidence that helps reconcile conflicting findings in the existing literature by examining the 4DSW in a distinct institutional and exposure setting. Prior studies from Oregon and Oklahoma document null or negative effects on some student outcomes, highlighting potential concerns related to instructional time compression, adjustment costs, and implementation challenges. These studies are conducted in contexts where the structure of the four-day schedule, the extent of instructional-hour preservation, and the timing of student exposure differ meaningfully across states. In contrast, Colorado's long history of adoption, binding instructional-hour requirements, and cohort-level exposure patterns allow us to study students who experience the 4DSW in a more stable and sustained environment, often beginning before entry into high school and continuing through completion. In this setting, districts adopting the 4DSW maintain instructional time, and we find modest but statistically significant improvements in English and mathematics achievement, a decline in dropout rates of approximately two percentage points, and increases in both on-time and overall graduation. Together, these results suggest that differences in institutional design and exposure structure play a central role in shaping the effects of the 4DSW, helping to explain why impacts vary across states.

Third, we document substantial heterogeneity in treatment effects. Students with longer and more consistent exposure prior to high school experience the largest gains in persistence and attainment, consistent with a cumulative human capital accumulation process and gradual adaptation to the schedule. Although most students benefit, some disadvantaged groups, including English learners and homeless students, experience smaller gains, indicating that equity considerations remain central to the evaluation of this reform.

Fourth, we examine mechanisms that help explain these effects. Analyses of implementation practices, teacher mobility, and district spending point to two primary channels: increased teacher retention and greater classroom investment, both of which contribute to more stable instructional environments. We further show that outcomes are similar across districts that take Monday versus Friday off, but that attainment gains are more persistent among Monday off adopters, suggesting that the organization of instructional time may interact with broader institutional responses to the reform. Together, these findings help reconcile conflicting evidence across states and clarify the conditions under which the four day school week can support student success.

Overall, this paper provides policy relevant evidence on one of the most rapidly expanding school reforms in the United States. By documenting both average effects and heterogeneity across student groups and implementation contexts, the study offers guidance for states and districts considering adoption of the 4DSW.

The remainder of the paper proceeds as follows. Section 2 describes the institutional background of the 4DSW nationally and in Colorado. Section 3 presents a conceptual framework. Section 4 outlines the data and empirical strategy. Section 5 reports the main results and robustness checks. Section 6 investigates mechanisms, and Section 7 concludes.

2. Background of Four-Day School Week

The 4DSW is an alternative scheduling model in which students attend school four days per week rather than the traditional five. To satisfy state instructional-hour requirements, districts typically lengthen each instructional day by approximately 60 to 90 minutes (CDE, 2024). The model first emerged during the Great Depression as a response to fiscal pressures and later reappeared during the energy crises of the 1970s, when districts sought to reduce operating costs (Donis-Keller and Silvernail, 2009; Tharp, 2014). Although early adoption was motivated primarily by cost considerations, more recent implementations increasingly emphasize broader organizational objectives, including staffing flexibility, teacher recruitment, and schedule redesign (Tharp, 2014; Walker, 2020; Thompson, 2021).

The growth of the 4DSW has been substantial. More than 1,600 schools nationwide had adopted the schedule prior to the pandemic, and recent estimates indicate continued expansion across more than 20 states (Thompson, 2021; Morton, 2024). Adoption remains heavily concentrated in rural districts and western states, where schools frequently face declining enrollment, long transportation routes, limited fiscal capacity, and persistent difficulties attracting and retaining teachers (Thompson, 2021; Kilburn et al., 2021). Existing evidence further shows that districts adopting the 4DSW are typically smaller and more geographically dispersed than traditional districts and often view the schedule as a form of non-pecuniary compensation in teacher labor markets (Walker, 2020; Thompson, 2021).

Colorado shares many of the characteristics associated with 4DSW adoption nationally, including a strong rural presence and the staffing and transportation challenges common among adopting districts. At the same time, the state stands out because adoption is unusually extensive. The state legislature formally authorized alternative school calendars in 1980, though adoption remained limited initially. CDE later formalized the approval process by requiring districts operating fewer than 160 instructional days to obtain state approval (CDE, 2024), and adoption accelerated during the early 2000s following the Great Recession. By the 2023–2024 academic year, 132 of Colorado's 187 districts, more than 70 percent statewide, operated under the 4DSW, tripling adoption over the previous two decades (CDE, 2024). More than 80 percent of students in rural districts attend schools operating under the 4DSW, compared with approximately 11 percent in non-rural districts. As the largest adopter nationally, Colorado provides extensive exposure histories and substantial variation in implementation timing across districts. Figure 1 illustrates the geographic distribution of adoption across the state.

Beyond the scale of adoption, Colorado's implementation of the 4DSW also differs systematically from traditional five-day districts. Standard calendars typically consist of approximately 160 instructional days with about six instructional hours per day. By contrast, 4DSW districts average roughly 144 instructional days with approximately 7.5 instructional hours per day and most commonly operate Monday through Thursday or Tuesday through Friday schedules (CDE Office of Field Services, 2016; CDE, 2024). Colorado further requires districts to satisfy the statewide minimum of 1,080 instructional hours annually, preserving total instructional exposure despite fewer instructional days.

Flexibility on the non-instructional day is another defining feature of implementation. Teachers frequently use the additional day for lesson preparation, grading, professional development, and administrative tasks (Walker, 2020). Students may participate in extracurricular activities, enrichment programs, community service, family responsibilities, or employment. Some districts also provide tutoring, remedial instruction, supervised programming, or childcare support intended to offset potential learning losses, although the availability and intensity of these services vary considerably across districts (Clear Creek School District RE 1, n.d.).

Taken together, Colorado combines large-scale adoption with extensive exposure histories and meaningful variation in implementation timing. These features provide a unique opportunity to evaluate the effects of the 4DSW in a mature policy environment while maintaining relevance to the broader set of districts considering or currently operating under alternative school calendars.

3. Conceptual Framework

While Section 2 describes the institutional background and implementation of the 4DSW, this section develops a conceptual framework that clarifies the channels through which the policy may affect high school outcomes. We adopt a production function and potential outcomes perspective to organize the mechanisms of interest and guide interpretation of the empirical results. The framework emphasizes that the 4DSW represents not simply a reduction in instructional days, but a broader reorganization of educational production that may alter instructional time, instructional quality, teacher labor supply, and student behavior both inside and outside of school. Importantly, these responses may evolve over time as students, teachers, and schools adapt to the schedule, implying that treatment effects may depend on both the duration and timing of exposure.

Let Y_{ist} denote an educational outcome for student i in school s and year t, including achievement, persistence, or graduation. The potential outcome under school schedule $D_{st} \in \{0,1\}$, where $D_{st} = 0$ denotes a traditional five day schedule and $D_{st} = 1$ denotes the 4DSW, is given by

$$Y_{ist}(D_{st}) = \mathscr{F}\big(T_{st}(D_{st}), \phi_{st}(D_{st}), Q_{st}(D_{st}), C_{ist}(D_{st}); X_{ist}, Z_{st}\big) + \varepsilon_{ist},$$

where T_{st} represents total instructional time, ϕ_{st} captures instructional productivity, Q_{st} denotes teacher quality and effectiveness, and C_{ist} reflects student inputs outside of school, including how students allocate time on the non instructional day. X_{ist} denotes student characteristics, Z_{st} captures school and district conditions such as rurality, labor market constraints, and fiscal capacity, and ε_{ist} is an idiosyncratic shock.

Instructional time can be expressed as

$$T_{st} = d_{st} h_{st},$$

where d_{st} denotes the number of instructional days and h_{st} denotes the length of the school day. Adoption of the 4DSW mechanically reduces d_{st} from five to four, but districts often ex-tend daily instructional hours to partially or fully offset the reduction in days. Consequently, total instructional time may increase, decrease, or remain approximately constant depending on implementation. However, learning depends not only on total instructional hours but also on the productivity of those hours. Let instructional productivity per hour be represented by

$$g\big(\phi_{st}(D_{st}), h_{st}(D_{st})\big),$$

where longer school days may generate either gains through reduced transitions and greater scheduling flexibility or losses through fatigue and diminished concentration. Weekly in school learning can therefore be written as

$$\mathscr{L}_{\text{school}}(D_{st}) \;=\; d_{st}(D_{st}) \cdot h_{st}(D_{st}) \cdot g\big(\phi_{st}(D_{st}), h_{st}(D_{st})\big).$$

The overall effect of the 4DSW on learning is therefore theoretically ambiguous even when instructional hours are preserved.

The policy may also affect educational outcomes through changes in teacher labor supply and instructional stability. A shorter school week may improve recruitment and retention by increasing schedule flexibility and reducing burnout, thereby improving teacher quality and continuity:

$$Q_{st}(1) \;=\; Q_{st}(0) + \Delta Q_{st}, \qquad \Delta Q_{st} \gtrless 0.$$

At the same time, compressed schedules may increase instructional strain or reduce opportunities for remediation and enrichment, potentially offsetting these gains. Because high school instruction relies heavily on subject specialization, course sequencing, and teacher continuity, changes in teacher retention may be particularly consequential at the secondary level.

Student responses outside of school may also adjust under the 4DSW. Let

$$C_{ist}(1) \;=\; C_{ist}(0) + \Delta C_{ist}, \qquad \Delta C_{ist} \gtrless 0,$$

where ΔC_{ist} captures changes in how students use the non instructional day. Additional flexibility may increase rest, tutoring, extracurricular participation, or school engagement for some students. However, adolescents also face meaningful opportunity costs of time, including part time work, caregiving responsibilities, and household obligations. As a result, some students may substitute away from academic investment toward labor market or family responsibilities. These responses are likely to vary across socioeconomic groups and household environments, implying heterogeneous effects across students.

The effects of the 4DSW may further depend on cumulative exposure and adaptation. Students exposed to the schedule for multiple years may gradually adjust to longer instructional days and altered weekly routines, while schools and teachers may improve implementation over time. Conversely, short run disruption costs may be largest immediately following adoption. These dynamics imply that treatment effects may differ across cohorts depending on both the timing and duration of exposure to the 4DSW.

Because adoption of the 4DSW is concentrated in rural districts, contextual factors Z_{st} may also systematically interact with the policy. Local labor markets, transportation constraints, childcare availability, and district fiscal capacity may all influence how schools implement the schedule and how students allocate time outside of school. Consequently, treatment effects may vary not only across students but also across institutional environments.

The average treatment effect of the 4DSW can therefore be interpreted as reflecting changes across multiple potentially offsetting channels:

$$\tau \equiv \mathbb{E}\big[Y_{ist}(1) - Y_{ist}(0)\big]$$

$$= \frac{\partial \mathscr{F}}{\partial T}\Delta T + \frac{\partial \mathscr{F}}{\partial \phi}\Delta \phi + \frac{\partial \mathscr{F}}{\partial Q}\Delta Q + \frac{\partial \mathscr{F}}{\partial C}\Delta C + \text{interaction terms.}$$

The sign of τ is theoretically ambiguous. Instructional time may rise or fall, instructional productivity may improve or deteriorate with longer school days, teacher quality may respond positively or negatively to labor market incentives, and student investments outside of school may vary according to household constraints and local conditions. These competing mechanisms imply no clear ex ante prediction regarding the overall effect of the 4DSW on student achievement or attainment. Empirical analysis is therefore necessary to determine whether, in practice, the 4DSW enhances or hinders long run human capital formation.

4. Data and Method

4.1 Data

Our analysis draws on comprehensive administrative records from the Colorado Department of Education (CDE), covering the universe of public school students and teachers from the 2003–2004 through the 2022–2023 academic years. The student-level data include demographic characteristics (race, gender), academic attributes (gifted status, English learner status, migrant status), and a broad set of educational outcomes, including standardized test participation, performance, grade repetition, dropout, and graduation. Unique student identifiers allow us to construct longitudinal records spanning elementary school through high school, enabling precise measurement of educational trajectories, timing of exposure to the 4DSW, and cumulative exposure prior to high school completion.

The teacher-level data provide information on demographics, professional characteristics such as years of experience, subjects taught, and detailed employment histories across schools and districts. These records allow us to examine teacher retention, transfers, and exits from the profession as potential mechanisms through which the 4DSW may influence student outcomes. We further supplement the administrative records with school- and district-level characteristics, including enrollment size, student composition, expenditures, and rural designation. These variables help account for systematic differences across districts that may be correlated with both 4DSW adoption and student outcomes.

Information on 4DSW adoption is obtained directly from the CDE and includes district identifiers and the year of first implementation. While a small number of districts adopted a four-day schedule prior to 2000, our observation window begins in the 2003–2004 academic year, with the majority of adoptions occurring after the 2008 financial crisis. Districts operating under reduced-calendar waivers are not formally required to verify implementation status. However, discussions with CDE officials indicate that nearly all waiver recipients transition to a four-day schedule, suggesting limited scope for treatment misclassification. We link district-level adoption records to individual student enrollment histories in order to measure both contemporaneous and cumulative exposure to the 4DSW.

Although the administrative data include all Colorado public school students in grades 1 through 12, our baseline sample consists of first-time ninth-grade entrants from the 2004–2005 through the 2019–2020 cohorts. The 2004–2005 cohort is the first for which statewide standardized test scores are consistently available, and restricting entry cohorts through 2019–2020 ensures that each cohort can be followed through the end of high school. This design allows us to observe complete attainment outcomes, including dropout, on-time graduation, and overall graduation. Focusing on first-time ninth-grade entrants also centers the analysis on the transition into high school, the stage at which educational persistence and completion become most salient.

To ensure a well-defined treatment structure, we exclude students enrolled in districts that adopted the 4DSW and subsequently returned to a traditional five-day schedule, eliminating cases in which treatment status turns on and off over time. These districts account for fewer than one percent of the full sample.[1] Finally, we examine heterogeneity in exposure timing by distinguishing between students first exposed to the 4DSW during high school and those first exposed during middle school.[2]

4.2 Outcomes

We examine student outcomes across three domains: academic performance, educational pro-

[1] Because four-day schedules are disproportionately adopted in rural districts, robustness checks further restrict the comparison group to districts that are observationally similar to treated districts using both propensity score matching and a random forest classifier.

[2] Students first exposed during elementary school are excluded because evaluating their high school outcomes requires a substantially longer observation window, yielding a smaller and more selective sample.

gression, and educational attainment. Together, these outcomes allow us to evaluate both immediate academic responses to the 4DSW and broader changes in students' educational trajectories that are central to human capital accumulation. Because much of the existing literature focuses primarily on test score effects, our analysis places particular emphasis on progression and attainment outcomes that capture persistence through high school completion.

Academic performance is measured using standardized English and mathematics test scores from statewide high school assessments. Prior to the 2016–2017 academic year, Colorado administered the ACT to all public high school students; beginning in 2016–2017, the state transitioned to the SAT. To ensure comparability across test formats and cohorts, all scores are standardized within administration year across all districts to have mean zero and unit standard deviation. We additionally examine test participation to assess whether changes in observed achievement reflect compositional shifts in testing behavior rather than underlying academic performance.

Progression outcomes capture students' movement through high school and include grade repetition and dropout. Grade repetition is defined as whether a student repeats any grade during high school. Dropout is defined using CDE administrative records indicating whether a student exits the Colorado public school system prior to earning a high school diploma. Attainment outcomes measure successful high school completion and include on-time graduation, defined as graduating within four years of entering ninth grade, and overall graduation, which additionally includes students who complete high school after more than four years. These outcomes represent economically meaningful margins of educational attainment and are strongly linked to later earnings, labor-market outcomes, health, and social mobility.

We also examine teacher outcomes, which primarily serve to illuminate potential mechanisms underlying the estimated student effects.[3] These outcomes include: (i) retention, defined as remaining in the same school from one year to the next; (ii) transfer, defined as leaving the current school to work in another Colorado public school; and (iii) exit, defined as leav-

[3]Teacher outcomes are used for mechanism analysis and are discussed in detail in Section 6.

ing the Colorado public school system entirely. These categories are mutually exclusive. The teacher data further include detailed information on gender, race, experience, degree attainment, grade levels taught, and instructional subjects. Examining these outcomes allows us to evaluate whether the 4DSW influences workforce stability and instructional continuity within schools, both of which may affect student persistence and attainment.

Finally, we examine outcomes related to instructional time and district expenditures to better understand differences in implementation across settings. Prior work on Oregon's 4DSW attributes declines in achievement largely to reductions in instructional hours (Thompson, 2021). By contrast, Colorado imposes binding minimum instructional-hour requirements on districts adopting the 4DSW, potentially contributing to the more favorable outcomes observed in our setting. We therefore test directly whether adoption of the 4DSW alters total instructional hours in Colorado. In addition, we analyze district expenditures to assess whether compressed schedules are associated with changes in the allocation of instructional and non-instructional resources. Together, these measures help clarify whether Colorado's experience reflects distinct implementation practices and resource adjustments that reconcile our findings with prior evidence from other states.

4.3 Summary Statistics

Table I presents summary statistics for districts operating under the 4DSW before and after adoption, alongside traditional five-day districts. These comparisons provide descriptive context for the empirical analysis, characterize the populations served by adopting districts, and highlight observable differences that motivate the identification strategy used throughout the paper.

Panel A reports student composition and educational outcomes. Overall, students in 4DSW and five-day districts are similar across many observable dimensions, though modest differences remain. The share of male students is nearly identical across groups at approximately 51 percent. Racial and ethnic composition differs somewhat: 4DSW districts serve a slightly smaller share of White and Asian students and a larger share of Hispanic students, while Black students constitute a smaller share of enrollment relative to five-day districts. Other indicators, including English learner status, migrant status, gifted designation, and homelessness, are broadly comparable across the two groups.

Academic outcomes indicate that students in 4DSW districts begin from modestly weaker baselines. Average English and mathematics performance is lower relative to students in traditional five-day districts, and attainment outcomes also lag slightly prior to adoption. On-time graduation and overall graduation rates are lower, while dropout rates are modestly higher. These differences are consistent with the concentration of 4DSW adoption among smaller and more rural districts that historically face greater constraints related to staffing, transportation, and resource availability. Importantly, these baseline differences imply that simple cross-sectional comparisons are unlikely to recover causal effects and motivate the use of within-district variation over time in the empirical analysis.

Panel B reports teacher characteristics and labor-market outcomes. Teacher demographics are broadly similar across 4DSW and five-day districts, with only modest differences in gender and racial composition. Differences are somewhat more pronounced in educational attainment: teachers in 4DSW districts are more likely to hold a bachelor's degree and less likely to hold a master's degree than teachers in five-day districts. Teachers in adopting districts also have slightly more experience on average, approximately 9.7 years compared with 9.1 years in traditional districts.

Teacher labor-market outcomes are likewise comparable across settings. Retention rates are somewhat higher in 4DSW districts, at approximately 76 percent, while exit rates are modestly lower at roughly 18 percent. Transfer rates differ little between the two groups. Although descriptive, these patterns are consistent with the possibility that adopting districts experience somewhat greater workforce stability, a mechanism examined more formally in Section 6.

Panel C reports district characteristics. Consistent with prior work, districts adopting the 4DSW tend to be smaller and more rural than traditional five-day districts. These differences highlight the institutional environment in which the policy operates and reinforce the importance of accounting for systematic differences in district composition and local conditions. Because adoption is concentrated in districts with distinct demographic and organizational characteristics, the empirical analysis emphasizes within-district comparisons over time and implements additional robustness checks to ensure comparability between treated and untreated districts.

Taken together, the descriptive statistics indicate that students in 4DSW districts are broadly comparable to those in traditional districts across many observable characteristics but enter from somewhat weaker academic baselines and are disproportionately concentrated in smaller rural settings. These patterns underscore the importance of accounting for both observable differences and institutional context when estimating the effects of the 4DSW.

4.4 Econometric Method

We begin by examining the impacts of 4DSW on student outcomes using variation in when and where schools adopted 4DSW in a generalized difference-in-differences framework. Specifically, we estimate the following equation:

$$Y_{icsd} = \beta_1 G1_{cd} + \beta_2 G2_{cd} + X'_{icsd} + \theta_s + \lambda_c + \epsilon_{icsd} \tag{1}$$

where Y_{icsd} is the outcome of interest, such as an indicator equal to one if student i in school s, district d, and high school entry cohort (9th grade) c drops out during high school. The indicator $G2_{cd}$ takes the value one for cohorts that entered ninth grade in the year of, or after, the adoption of the 4DSW in district d, ensuring full exposure throughout high school. Our main outcomes, including English and math test scores, dropout, and graduation, are typically realized several years after students first enter high school (most often around 12th grade).[4] The coefficient β_2 therefore captures the average effect for cohorts that were fully exposed to the 4DSW from the start of high school. By contrast, earlier cohorts may have been only partially exposed beginning in 10th, 11th, or 12th grade. To account for this, we include a second indicator, $G1_{cd}$, which equals one for cohorts that entered high school one to three years prior to the 4DSW adoption in their districts. Thus, $G1_{cd}$ identifies students who were not exposed in ninth grade but encountered the 4DSW later in high school, and β_1 measures the effect of this partial exposure.

The model also includes a vector of controls, $X^{'}_{icsd}$, to account for observed student, teacher, school, and district characteristics. θ_s denotes school fixed effects to absorb any school-level time-invariant confounding factors, while λ_c denotes entry-cohort fixed effects. ϵ_{icsd} is the error term. Robust standard errors are clustered at the district level.

Furthermore, for mechanism analysis purpose, we explore how 4DSW affects teacher outcomes, such as retention, transfer, and turnover. To do so, we estimate a similar equation to equation (1) but exclude the partial treatment indicator, as teacher outcomes can be observed at the school-year level. The model is specified as follows:

$$Y_{jsdt} = \beta_1 G_{dt} + X^{'}_{jsdt} + \theta_s + \lambda_t + \epsilon_{jsdt} \tag{2}$$

where Y_{jsdt} denotes the outcome for teacher j in school s and district d in school year t; X'_{jsdt} is a vector of controls; θ_s and λ_t are school and school-year fixed effects, respectively. Robust standard errors are clustered at the district level.

The baseline DiD approach summarizes impacts over the outcome time horizon. To exam-

[4]A potential concern is that some outcomes are observed only for students who remain enrolled through the relevant grade level, which could introduce sample selection if the four day school week affects persistence. In Colorado, however, the minimum legal dropout age is seventeen, so nearly all students remain enrolled through the end of eleventh grade. Consequently, standardized test taking and course repetition, which occur before twelfth grade, are measured prior to the earliest dropout age and observed for the full student population. Only graduation, realized at the end of twelfth grade, is mechanically conditional on persistence. To address this, we estimate effects on both dropout and graduation, capturing the extensive and intensive margins of high school completion and mitigating concerns about endogenous sample selection.

ine how effects vary by the timing of exposure, we further estimate the following event-study equation:

$$Y_{icsd} = \sum_{k=-7, k\neq -4}^{k=3} \beta_k G_{cd}^k + \beta_2 X_{icsd}^{'} + \theta_s + \lambda_c + \epsilon_{icsd} \tag{3}$$

where the indicator variable G_{cd} is replaced by an event-year indicator G^k. All other variables are defined as same as equation (1). The event windows are seven years prior to and three years after 4DSW.[5] The student cohorts where $k = \{-1, -2, -3\}$ years from the fully treated cohorts ($k = 0$) are considered partially treated cohorts. The omitted category is the last fully untreated cohort, $k = -4$.[6]. Coefficients corresponding to the years after 4DSW (β_k for $k \geq 0$) captures the post-adoption treatment effects that occur in response to 4DSW over time.

4.5 Threats to Identification

A major threat to our DiD framework is the violation of the parallel trends assumption. While the event study model in equation (3) estimates the post-treatment effect of the 4DSW, it can also be used to test for parallel trends. If lagged effects exist, our identification strategy is likely invalidated. Figure 2 depicts the dynamics of the 4DSW effect on various outcomes. In all cases, the pre-adoption coefficients are small in magnitude and statistically insignificant, providing little evidence of pre-trends.[7]

Although the lack of large and significant pre-treatment effects supports the causal interpretation under the DiD framework, the conventional two-way fixed effects (TWFE) model is not

[5] The event time window extends three cohorts beyond the adoption year because majority of the treated districts can be consistently observed for at least three subsequent ninth grade entry cohorts. In addition, the plus one to plus three cohorts likely include students who were first exposed to the 4DSW during middle school, assuming they remained in the same district, thereby capturing early treated students with prior exposure to the policy before entering high school.

[6] As for teacher outcomes, there is no partial treatment issue, so the omitted category is $k = -1$. Specifically, we estimate the event-study equation for teacher as:

$$Y_{jsdt} = \sum_{k=-7, k\neq -1}^{k=3} \beta_k G_{dt}^k + \beta_2 X_{jsdt}^{'} + \theta_s + \lambda_t + \epsilon_{jsdt} \tag{4}$$

All variables are defined as same as in equation (2).

[7] The coefficients for periods prior to 4DSW adoption are jointly insignificant at conventional significance levels.

well suited for testing pre-trends, particularly when treatment is staggered and effects are heterogeneous (Sun & Abraham, 2021; Goodman-Bacon, 2021; Borusyak et al., 2022). In such settings, unless treatment effects are homogeneous, β_k is a linear combination of group-specific effects from both its own and other relative periods. As a result, treatment effects from other periods may contaminate the estimate of β_k. To address this concern, we re-estimate the event study model using the "interaction-weighted" estimator proposed by Sun and Abraham (2021). Figure 3 presents the coefficient plots. The alternative method also shows little evidence of pre-trends, strengthening the credibility of our DiD design.

The difference in differences and event study models require that adoption of the 4DSW be unrelated to any preexisting trend in long run outcomes across school districts. We present two empirical checks of this assumption. We begin by assessing whether adoption was preceded by systematic movements in district characteristics. To investigate this, we estimate a modified event study that replaces the pre 4DSW indicators with a single linear trend:

$$Y_{dt} = \alpha_1 \textbf{year\_before\_4DSW} + \sum_{k=1}^{3} \gamma_k (\textbf{year\_after\_4DSW} = k) + \beta_2 X_{dt} + \theta_d + \lambda_t + \varepsilon_{dt}, \tag{5}$$

where Y_{dt} denotes district-level characteristics, **year_before_4DSW** is a linear time trend in the years prior to a district's adoption, and θ_d and λ_t are district and year fixed effects. The coefficient α_1 captures the slope of outcomes prior to 4DSW adoption. Table A.1 reports the estimates. Across the characteristics considered, only one coefficient is statistically significant. Second, we examine the association between the year of 4DSW adoption and baseline district characteristics.[8] Table A.1, Column (2), provides no evidence of such a relationship, indicating that adoption was not systematically driven by initial district conditions.

We then assess whether the timing of 4DSW adoption is systematically related to pre-policy values of the outcome variables among adopting districts. Specifically, we regress the year of adoption on the two-, three-, and four-year averages of each outcome variable prior to implementation. As indicated by Table A.2, across all specifications, the coefficients are small and

[8]The baseline year is the initial data year 2005.

statistically indistinguishable from zero. These findings indicate that the sequence of adoption is not driven by prior differences in student or teacher outcomes, supporting the identifying assumption that variation in adoption timing is plausibly exogenous to underlying outcome dynamics.

Next, we examine whether adoption of the 4DSW induces student mobility that could bias the estimated effects. Two forms of movement are relevant. The first is within-state transfers, where families relocate between districts to seek or avoid a four-day schedule.[9] Such sorting could alter district composition and confound causal interpretation. The second is attrition from the public system, in which students leave Colorado's administrative records entirely through private schooling, homeschooling, or out-of-state migration. Table A.3 shows that adoption of the four-day week does not significantly affect district demographics or total enrollment, while Table A.4 directly tests both forms of mobility using the full student panel.[10] The estimates reveal no change in the likelihood of transferring to another district or exiting the state public system prior to graduation. Overall, these results indicate that four-day adoption does not induce selective migration or attrition, supporting the credibility of the identification strategy.

5. Results

5.1 Student-Level Outcomes

Table II reports difference-in-differences estimates of the effect of adopting the 4DSW on high school outcomes. All specifications include school and ninth-grade entry cohort fixed effects, along with a rich set of student, school, and district controls.

We begin with achievement outcomes. We find no evidence that the 4DSW affects standard-

[9] For example, a student may transfer from a five-day district to a four-day district, or vice versa, due to preferences related to scheduling, commuting, or child-care logistics.

[10] Specifically, Table A.4 examines (i) whether students in any grade are more likely to switch school districts after adoption of the 4DSW, and (ii) whether students previously observed in the state's public data later fail to reappear — either before entering high school (entry margin) or before graduation (exit margin) — without being classified as dropouts.

ized test participation, with estimates that are small and statistically indistinguishable from zero. Test performance, however, improves modestly under full exposure to the policy. English scores increase by 0.027 standard deviations, significant at the 5 percent level, and mathematics scores by 0.025 standard deviations, significant at the 10 percent level. Although modest in magnitude, these estimates are comparable to effects reported for several widely studied school-based interventions and accountability reforms (Hanushek and Raymond, 2005; Dee and Jacob, 2011). Using the common benchmark that a 0.25 standard deviation increase corresponds to approximately one grade-level year of learning, the estimated gains imply roughly one additional month of academic progress (Bloom et al., 2008). By contrast, estimates for students first exposed to the 4DSW after ninth grade are smaller and imprecisely estimated, suggesting that achievement gains are concentrated among cohorts with more sustained exposure.

Turning to progression outcomes, we find no detectable effect on grade repetition. Dropout, however, declines substantially under full exposure to the 4DSW. The estimated reduction of 2.1 percentage points corresponds to an 18 percent decrease relative to the control-group dropout rate of 11.8 percent. This effect is both statistically and substantively meaningful, particularly in Colorado, where students are legally permitted to leave school at age 17. The results therefore suggest that the 4DSW may play an important role in retaining marginal students during the period when school exit becomes feasible. Partial exposure yields smaller and statistically insignificant effects, further indicating that sustained exposure is important for persistence outcomes.

The largest effects emerge for attainment outcomes. Under full exposure, overall graduation increases by 3.2 percentage points and on-time graduation by 2.9 percentage points, both statistically significant at the 1 percent level. These estimates correspond to increases of approximately 4.3 percent and 4.0 percent relative to baseline graduation rates of 74.7 and 73.2 percent, respectively. Students first exposed to the 4DSW after ninth grade also experience positive attainment effects, with graduation and on-time graduation rising by approximately 1.3 to 1.4 percentage points. Although smaller in magnitude, these estimates suggest that even partial exposure may improve completion outcomes, while the largest and most consistent gains accrue to students exposed continuously from the beginning of high school onward.

To place these estimates in context, the magnitude of the attainment effects is economically meaningful relative to prior evidence in the education literature. Jackson et al. (2020), for example, show that improvements in school quality are associated with increases in high school graduation. The estimated effects of the 4DSW in Colorado are comparable in magnitude to those reported for several school-based interventions aimed at improving educational attainment. Although the estimated percentage-point changes may appear modest at the individual level, their aggregate implications are substantial when applied across large student populations. Applying the estimates to a cohort the size of Colorado's annual public high school population of approximately 68,000 students (CDE, 2025) implies sizable reductions in dropout and corresponding increases in graduation and on-time completion. These aggregate gains are potentially important given the well-documented long-run returns to high school completion, including higher earnings, improved labor market outcomes, and lower rates of criminal involvement (Lochner and Moretti, 2004; Oreopoulos and Salvanes, 2011; Heckman, 2006).

Our findings also differ notably from prior evidence in Oregon. Thompson et al. (2021) document declines of approximately 0.09 standard deviations in test scores and reductions of four to five percentage points in graduation rates, with little corresponding change in dropout. In Colorado, by contrast, we observe improvements in both achievement and attainment outcomes. This contrast suggests that the effects of the 4DSW depend importantly on institutional context and implementation. In Oregon, adoption was accompanied by substantial reductions in instructional hours, directly reducing time spent in school. In Colorado, districts largely maintain required instructional hours and often reallocate operational savings toward classroom resources and teacher support, suggesting that reductions in instructional time are unlikely to be the primary mechanism driving outcomes in our setting (see Section 6). More broadly, these results reinforce the idea that school schedules interact with organizational practices, staffing decisions, and resource allocation in shaping student outcomes. As emphasized by Jackson et al.

(2020), schools influence students through multiple academic, behavioral, and organizational channels, and the relative importance of these mechanisms may vary substantially across institutional environments. Understanding these channels is therefore central to explaining why similar schedule reforms can generate divergent effects across states.

5.2 Duration of Exposure

The results in Table II indicate that students fully exposed to the 4DSW throughout high school experience larger gains in persistence and attainment than those exposed only later, suggesting that the duration of exposure plays an important role in shaping outcomes. This pattern raises a natural question: do the effects of the 4DSW depend on when students are first introduced to the policy and how long they remain exposed? To address this question, we estimate separate effects for cohorts first exposed in middle school and for those whose exposure begins only after entry into high school.[11] Table III summarizes the results.

The evidence reveals a clear pattern of heterogeneous but consistently positive effects. For students first exposed to the 4DSW during high school, the estimates indicate modest improvements in both performance and attainment. Test participation remains unchanged, while English and mathematics scores increase by approximately 0.02 to 0.03 standard deviations. Dropout declines slightly but remains statistically indistinguishable from zero. Graduation and on-time graduation, however, increase by approximately 1.6 to 1.7 percentage points. These findings suggest that even relatively limited exposure to the 4DSW during high school may improve educational attainment, although the estimated effects remain modest in magnitude.

By contrast, students first exposed to the 4DSW in middle school experience larger and more precisely estimated gains. English and mathematics scores increase by approximately 0.02 standard deviations, while dropout declines by roughly 1.9 percentage points. Graduation and on-time graduation rates rise by more than 4 percentage points, with both effects statistically sig-

[11] Students first exposed in elementary school are excluded because requiring continuous records from elementary through high school substantially reduces sample size and statistical power.

nificant at conventional levels. Relative to students first exposed only during high school, earlier exposure produces substantially larger improvements in persistence and completion, indicating that the benefits of the 4DSW accumulate over time.

Panel C further reveals a clear dose–response relationship between exposure length and educational outcomes. Each additional year of exposure to the 4DSW increases graduation and on-time graduation rates by approximately 0.6 to 0.7 percentage points and reduces dropout by roughly 0.4 percentage points, with all estimates statistically significant. These results indicate that the effects of the 4DSW emerge gradually rather than immediately upon adoption, allowing relatively small annual gains to compound into meaningful improvements in educational attainment over time.

Taken together, these findings demonstrate that both the timing and duration of exposure are central to understanding the effects of the 4DSW. Exposure beginning prior to high school generates the largest and most persistent improvements in attainment. One possible explanation is that longer exposure allows students more time to adapt to altered schedules and develop routines that reinforce persistence and engagement. In addition, schools and districts operating under the 4DSW for longer periods may gradually adjust instructional practices, staffing patterns, and organizational routines in ways that improve implementation quality over time. By contrast, students first encountering the policy during high school have less opportunity to adjust before key educational transitions occur. Overall, the evidence indicates that sustained and stable implementation, rather than short-term or partial exposure alone, is important for realizing the longer-run benefits of the 4DSW.

5.3 Do All Students Benefit Equally

Table IV examines heterogeneity in the effects of the 4DSW across student subgroups. The analysis assesses whether improvements in achievement, progression, and attainment differ systematically across demographic and disadvantaged student populations.

By gender, the estimated effects are broadly similar across most outcomes. Both male and female students experience statistically significant improvements in persistence and attainment, including reductions in dropout and increases in graduation and on-time graduation. Achievement gains are somewhat larger and more precisely estimated for male students, particularly in mathematics, although the estimated effects remain positive for both groups. Taken together, the results indicate relatively limited heterogeneity by gender, with only modest differences in test score responses.

Across racial and ethnic groups, the estimated effects on attainment are generally positive, although the magnitude and precision of the estimates vary across subgroups. White and Hispanic students exhibit statistically significant improvements in both achievement and attainment outcomes. Estimated effects for Black students are also positive in most specifications but are less precisely estimated, reflecting smaller sample sizes and greater underlying variation in outcomes. Overall, the results provide little evidence that the benefits of the 4DSW are concentrated exclusively among a single racial or ethnic group, although the precision of subgroup estimates differs considerably across populations.

More substantial differences emerge for students facing socioeconomic and educational disadvantage. English learners and homeless students experience smaller and less consistent gains, with some estimates, particularly for achievement outcomes, close to zero or negative. Because these subgroups represent a relatively small share of the sample, the estimates are less precise and should be interpreted cautiously. Nevertheless, the overall pattern suggests that students who rely more heavily on school-based instructional and support services may benefit less from a shortened school week. For these students, reduced in-school structure or limited access to academic supports on the non-instructional day may offset some of the gains observed for other groups. These findings highlight the potential importance of complementary supports, such as targeted tutoring, language services, or supervised programming, in shaping how alternative school schedules affect vulnerable student populations.

5.4 Robustness Checks

To assess the credibility of the baseline estimates, we conduct a comprehensive set of robustness and complementary analyses designed to address concerns related to covariate balance, model specification, treatment definition, sample composition, measurement, and statistical inference.

We begin by examining potential differences in observables between treated and control schools. Adoption of the 4DSW is concentrated in smaller and more rural districts, implying that treated students represent a relatively small share of the statewide student population despite adoption occurring across a substantial number of districts. To improve comparability, we implement propensity-score matching based on pre-treatment school characteristics predictive of adoption. Each treated school is matched to its nearest control schools using estimated propensity scores, without replacement, and the least comparable control observations are excluded.[12] The resulting estimates, reported in Table A.5 Panel A, closely resemble the baseline results, indicating that differences in observable characteristics are unlikely to explain the main findings.

To further assess covariate balance, we re-estimate adoption propensities using a random forest classifier, which flexibly captures nonlinearities and higher-order interactions among covariates without imposing parametric restrictions. Applying the same matching procedure based on these nonparametric predictions,[13] the estimates reported in Table A.5 Panel B remain nearly identical to the baseline. As an additional approach, we estimate inverse probability weighted (IPW) models that retain the full sample while reweighting observations so that the control group more closely matches the covariate distribution of treated schools. The IPW estimates reported in Table A.5 Panel C again closely align with the baseline results, reinforcing the conclusion that the findings are robust to alternative approaches for achieving covariate balance.

[12]Specifically, the analysis is restricted to schools whose estimated propensity scores fall between the 5th and 95th percentiles of the combined treated and control distribution, using 1:3 nearest-neighbor matching without replacement.

[13]The same 1:3 nearest-neighbor matching procedure is implemented using the random forest propensity estimates.

Next, we examine sensitivity to model specification. Estimating the baseline specification without any control variables yields coefficients that are highly similar to those from the fully controlled model, indicating that the results are not driven by covariate adjustment. Adding district-specific linear pre-trends to account for potential differences in underlying outcome trajectories across districts produces nearly identical estimates (Table A.5 Panel E). To assess whether the findings are disproportionately influenced by any single adopting district, we sequentially exclude each treated district and re-estimate the model. Figure A.3 shows that the estimated effects remain highly stable across exclusions, suggesting that no individual district drives the results.

We also evaluate sensitivity to the treatment definition. The baseline specification distinguishes between fully exposed cohorts and partially exposed cohorts consisting of students who begin high school under a traditional five-day schedule but subsequently experience 4DSW adoption while still enrolled. As a robustness check, we restrict the sample to cohorts fully exposed since ninth grade and cohorts never exposed during high school, excluding all partially treated cohorts. This restriction provides a cleaner comparison that does not rely on assumptions regarding the functional form of partial exposure. The resulting estimates, reported in Table A.6, remain highly consistent with the baseline findings.

To evaluate the influence of sample composition, we conduct several additional exercises. Restricting the analysis to students entering high school in 2015 or earlier, and therefore graduating prior to the Covid-19 pandemic, yields estimates closely comparable to the baseline. Excluding charter schools and Boards of Cooperative Educational Services, which operate under distinct governance and funding structures, produces similar results. Although 4DSW adoption in Colorado is concentrated primarily in rural districts, several urban and suburban districts also adopt the schedule. Restricting the sample to small rural districts yields estimates that remain highly consistent with the baseline findings, indicating that the results are not driven by non-rural adopters.[14]

We further assess the robustness of achievement outcomes to changes in statewide testing formats. Colorado administered the ACT prior to the 2016–2017 academic year and transitioned to the SAT thereafter. Although the baseline analysis standardizes scores across assessments, we re-estimate the models excluding all SAT-based cohorts and, separately, excluding all ACT-based cohorts. In both cases, the estimates remain virtually unchanged,[15] indicating that the transition in assessment format does not drive the achievement results.

Finally, we conduct a placebo inference exercise by randomly reassigning adoption years across districts 1,000 times and re-estimating the baseline specification. Figure 4 shows that the observed estimates lie in the extreme tails of the placebo distribution, with fewer than ten percent of simulated estimates exceeding the observed effects in absolute value. This exercise provides additional evidence that the estimated treatment effects are unlikely to arise from spurious correlations or random assignment of treatment timing.

Taken together, these robustness exercises demonstrate that the estimated effects of the 4DSW remain highly stable across a broad range of samples, specifications, treatment definitions, and inference procedures.

6. Potential Mechanisms and Discussion

6.1 Potential Mechanisms

Guided by the conceptual framework in Section 3, we next examine the primary channels through which the 4DSW may influence student outcomes. We focus on five mechanisms: (i) instructional time, (ii) variation in schedule implementation, (iii) teacher labor-market responses, (iv) changes in instructional and classroom resource expenditures, and (v) opportunities for student enrichment outside the traditional instructional day. Together, these analyses help ex-

[14] Rural districts are defined based on district size and distance from the nearest urbanized area, with enrollment of 6,500 or fewer students. Small rural districts satisfy the same criteria but enroll fewer than 1,000 students (CDE, 2025).

[15] Results excluding ACT-based cohorts are similar and available upon request.

plain why Colorado's experience with the 4DSW differs from the negative findings documented in several prior settings.

Among the most direct mechanisms, instructional time has received the greatest attention in the existing literature. Evidence from Oregon attributes a substantial share of the negative academic effects of the 4DSW to reductions in instructional hours (Thompson, 2020), consistent with broader research demonstrating that additional instructional time can improve academic performance (Rivkin and Schiman, 2015; Lavy, 2015). Colorado, however, operates under a distinct institutional environment. The Colorado Department of Education requires districts to provide a minimum of 1,080 instructional hours annually at the high school level (CDE, 2025), and districts adopting the 4DSW generally lengthen the school day to satisfy these requirements. Unlike the Oregon setting, we observe improvements rather than declines in both achievement and attainment, making it important to understand which mechanisms generate these positive effects.

To examine the role of instructional time directly, we first document average annual instructional hours among adopting districts (Figure A.4). All treated districts meet or exceed the state's minimum instructional-hour requirement, and many substantially exceed it. We then re-estimate the baseline specification using instructional hours as the dependent variable. As reported in Table A.9, districts adopting the 4DSW provide, on average, approximately 23 additional instructional hours annually, equivalent to roughly 0.56 additional hours per week.[16] The estimate is not statistically significant, but the results indicate that adoption of the 4DSW in Colorado does not reduce total instructional time. This distinction is important because it rules out the primary mechanism emphasized in prior work documenting adverse effects under substantial reductions in instructional hours.

We next examine whether the organization of the non-instructional day influences the effects of the 4DSW. In Colorado, districts retain discretion over which day of the week becomes non-instructional, with nearly all districts adopting either a Monday-off or Friday-off sched-

[16] Assuming approximately 160 instructional days under the four-day schedule.

ule.[17] These alternatives may generate different behavioral and organizational responses. A Monday-off schedule may allow students additional recovery time following weekend activities and reduce fatigue or absenteeism at the beginning of the instructional week (Carrell et al., 2011; Lo et al., 2016). By contrast, a Friday-off schedule extends the weekend and may increase opportunities for work, travel, or family obligations that affect engagement and continuity in learning (King, 2002). More broadly, prior research demonstrates that the organization and spacing of instructional time influence learning and retention (Patall et al., 2010; Pashler et al., 2007).

When we estimate the effects separately by non-instructional day, short-run academic outcomes appear remarkably similar across the two schedule types. Both Monday-off and Friday-off districts exhibit comparable effects on test performance and dropout, with no statistically meaningful differences in achievement outcomes. Friday-off districts show a modest increase in grade repetition, whereas Monday-off districts exhibit a slight decline, although the difference between the estimates is not statistically significant. The primary divergence emerges in longer-run attainment outcomes. Districts adopting a Monday-off schedule experience substantially larger increases in graduation and on-time graduation, approximately 2 to 3 percentage points larger than comparable Friday-off districts, while Friday-off districts exhibit smaller and statistically insignificant attainment gains. Despite similar short-run academic responses across the two schedule structures, the organization of instructional time across the week appears more consequential for longer-run persistence and completion decisions.

The evidence on instructional hours and non-instructional day scheduling indicates that these dimensions alone cannot fully account for the observed improvements in student outcomes under the 4DSW. We therefore next consider the teacher labor market, which occupies a central role in the educational production process described in Section 3. If the 4DSW alters teachers' working conditions or career decisions, these responses may directly influence student achievement and persistence. A substantial literature links teacher turnover and workforce

[17] Information on designated non-instructional days is obtained from the Colorado Department of Education and supplemented through manual collection from district and school websites.

instability to lower student performance, reduced school cohesion, and weaker educational attainment outcomes (Ronfeldt et al., 2013; Sorensen et al., 2021), making teacher retention a particularly important mechanism to examine.

Table V shows that adoption of the 4DSW increases high school teacher retention by approximately 2.7 percentage points, with the estimate statistically significant at conventional levels. Given that Colorado employs roughly 55,000 public high school teachers statewide (CDE, 2025),[18] this estimate corresponds to nearly 1,500 additional teachers remaining in their schools each year. By contrast, the estimated effects on teacher transfers across schools and exits from the profession are small and statistically indistinguishable from zero. The primary labor-market response to the 4DSW therefore appears to be greater workforce stability within schools rather than broader changes in teacher mobility.

One potential explanation is that the 4DSW improves teachers' non-pecuniary job quality without reducing compensation. As reported in Appendix Table A.11, adoption of the 4DSW does not significantly affect teacher salaries or benefits, meaning that teachers receive comparable compensation while working under a compressed four-day schedule. This effectively raises non-wage compensation by reducing commuting time and providing additional flexibility for lesson preparation, professional development, childcare, or other personal responsibilities. Prior work identifies schedule flexibility and work-life balance as important determinants of teacher retention and burnout (Anderson, 2015; Morton, 2020), making improved working conditions a plausible explanation for the retention gains observed under the 4DSW.

Because teacher retention emerges as the most consistent teacher-related response, we next assess whether the magnitude of this change is large enough to account for part of the observed student gains. Prior evidence shows that increases in teacher turnover reduce student achievement and persistence, with school-level losses on the order of several hundredths of a standard deviation for moderate increases in turnover (Ronfeldt et al., 2013; Sorensen et al., 2021). Benchmarking our estimates against these published elasticities indicates that the observed in-

[18]Results using the full statewide sample of teachers across all grade levels are similar and reported in Appendix Table A.8.

crease in teacher retention could account for approximately 10 to 20 percent of the estimated gains in achievement and attainment.[19] This back-of-the-envelope exercise nonetheless indicates that improved teacher stability represents a quantitatively meaningful channel through which the 4DSW strengthens student persistence and attainment.

Beyond teacher labor-market responses, we also examine whether districts reallocate financial resources toward classroom inputs under the 4DSW. We focus on instructional expenditures and supplies expenditures, which provide direct measures of resources available for day-to-day teaching and learning.[20] A large literature demonstrates that increases in instructional spending improve student achievement and long-run outcomes (Jackson et al., 2016), while more recent evidence highlights the importance of classroom materials and instructional supplies for academic performance (Harris, 2023). Related work in higher education further shows that reducing barriers to instructional materials improves persistence and completion (Open Praxis, 2023; Publishers Association, 2025).

Results reported in Appendix Table A.10 show that both instructional and supplies expenditures increase following adoption of the 4DSW. Instructional expenditures increase modestly and remain imprecisely estimated, whereas supplies expenditures rise by approximately 18 percent, equivalent to roughly $74 additional dollars per pupil annually.[21] This represents a meaningful increase in classroom resources and potentially improves the instructional environment. At the same time, the existing literature provides limited evidence regarding how expenditure increases of this magnitude translate into student achievement gains, so the results should be

[19]A back-of-the-envelope calculation based on published elasticities helps contextualize the magnitude of the retention effect. Ronfeldt et al. (2013) and Sorensen et al. (2021) estimate that a 10 percentage point increase in teacher turnover lowers average student achievement by approximately 0.02 to 0.05 standard deviations at the grade or school level. Reversing these estimates implies that comparable improvements in retention would raise achievement by roughly 0.02 to 0.05 standard deviations. Given that the 4DSW increases teacher retention by approximately 2.7 percentage points, a linear approximation implies achievement gains of roughly 0.005 to 0.014 standard deviations. Relative to the observed achievement effects of approximately 0.025 standard deviations in our data, this range corresponds to approximately 10 to 20 percent of the overall effect.

[20]Instructional expenditures include classroom-related spending tied directly to instruction. Supplies expenditures include items such as textbooks, classroom consumables, instructional technology, and materials used for teaching or enrichment activities. All expenditure measures are constructed at the district-year level and expressed on a per-pupil basis.

[21]Average district-level supplies expenditures equal approximately $412 per pupil annually.

interpreted as suggestive rather than definitive evidence of a resource channel.

Finally, we consider how students may use the additional non-instructional day created by the 4DSW. Although the schedule reduces the number of formal instructional days, some districts use the fifth day for enrichment programming, tutoring, athletics, extracurricular activities, or targeted academic support. Research on out-of-school time programs consistently finds that structured activities improve persistence, socio-emotional development, and engagement by providing supervision, mentoring, and opportunities for skill formation (Lauer et al., 2006; Fredricks and Eccles, 2006). Districts may also use the additional day for credit recovery or individualized tutoring, both of which improve high school completion and test performance (Dynarski and Gleason, 2002; Nickow et al., 2020).

To approximate these enrichment opportunities, we examine district expenditures on purchased services and community services.[22] These budget categories provide indirect measures of whether districts shift resources toward fifth-day programming under the 4DSW. As reported in Appendix Table A.11, however, we do not observe systematic increases in either expenditure category following adoption. These measures are imperfect proxies and cannot directly capture program quality or student participation. Nonetheless, the available evidence provides limited support for large-scale reallocations toward enrichment programming as the primary driver of the observed gains.

Taken together, the evidence indicates that Colorado's positive experience with the 4DSW is not driven by reductions in instructional hours and cannot be attributed solely to whether districts adopt a Monday-off or Friday-off schedule. Instead, the results point toward a broader set of organizational and resource-based adjustments, particularly improved teacher retention and modest increases in classroom-related expenditures. These channels likely contribute to the observed gains in persistence and attainment, though their relative importance remains difficult to isolate precisely. Other mechanisms, including changes in student fatigue, men-

[22] Purchased services typically include payments to external providers of educational or extracurricular programming, while community services expenditures encompass activities directed toward student and family engagement outside traditional classroom instruction. Expenditures are measured at the district-year level on a per-pupil basis.

tal health, parental labor supply, or school engagement, may also influence student outcomes but fall outside the scope of the current analysis and remain important directions for future research. Overall, the findings highlight that the effects of the 4DSW operate through a broader reorganization of the educational production process rather than through instructional time alone.

6.2 Discussion

To place the estimated attainment effects in economic context, we conduct a back-of-the-envelope calculation that translates the observed increases in high school graduation into approximate monetary values. Following Heller et al. (2017) and Cohodes et al. (2023), we treat each additional graduate as equivalent to one additional year of completed schooling relative to a dropout. We then monetize the implied gains through two channels: (i) higher lifetime earnings and (ii) improvements in health associated with increased educational attainment. We focus on graduation rather than intermediate outcomes because high school completion provides the clearest and most policy-relevant attainment margin examined in the paper and maps directly into a large literature estimating the economic and social returns to educational attainment.[23]

For earnings, we draw on synthetic work-life earnings profiles from Julian & Kominski (2011) and apply the conventional estimate that an additional year of schooling raises earnings by approximately 12 percent. Existing work estimates that high school completion generates a present discounted value of roughly $200,000 in additional lifetime earnings per graduate (Lochner & Moretti, 2004; Oreopoulos, 2007; Rouse, 2007). For health-related benefits, we follow Cutler & Lleras-Muney (2006) and assign an additional $28,750 per graduate, corresponding to the midpoint of their estimated range. On the cost side, and consistent with Cohodes et al. (2023), we proxy the resource cost of additional schooling using average per-pupil operating expenditures in Colorado, approximately $11,000 annually (CDE, 2025).

[23] By contrast, outcomes such as achievement, progression, or persistence, while important for understanding mechanisms and educational trajectories, are more difficult to translate into monetary values without imposing additional assumptions regarding their relationship to later outcomes.

Applying this framework to our estimates, the 4DSW increases the number of graduates by approximately 2,176 students per entering cohort of roughly 68,000 public high school students. Under the assumptions above, this corresponds to approximately $435 million in additional lifetime earnings and roughly $63 million in health-related benefits, offset by approximately $24 million in additional schooling costs. The implied net benefit is therefore approximately $474 million per cohort, equivalent to roughly $7,000 per entering student or approximately $218,000 per additional graduate.

These calculations are intended to be illustrative rather than a comprehensive welfare analysis. They abstract from several potentially important channels through which the 4DSW may affect social welfare, including changes in crime, civic participation, intergenerational mobility, parental labor supply, childcare burdens, and student well-being. In addition, the estimates rely on benchmark returns to educational attainment drawn from prior literature rather than directly estimating labor-market outcomes within our data. Nevertheless, the exercise demonstrates that even modest improvements in high school completion can imply economically meaningful aggregate returns when applied across large student populations.

7. Conclusion

This paper provides large-scale causal evidence on the effects of the 4DSW on high school students, drawing on nearly two decades of linked administrative records from Colorado that follow more than one million unique students across successive cohorts. The scale and longitudinal structure of the data allow us to evaluate not only short-run academic performance, but also longer-run measures of persistence and educational attainment that are central to human capital accumulation and economic mobility. We find that adoption of the 4DSW leaves test participation unchanged, modestly improves achievement, reduces dropout, and generates economically meaningful increases in both graduation and on-time graduation. When scaled to the size of a typical statewide cohort, these effects imply substantial aggregate gains in educational attainment and long-run human capital formation.

The analysis further demonstrates that the effects of the 4DSW depend critically on the timing and duration of exposure. Students with longer and more continuous exposure to the schedule, particularly those first exposed prior to entering high school, experience the largest and most consistent improvements in persistence and attainment. By contrast, students first exposed during high school exhibit smaller gains. These patterns indicate that the effects of alternative school calendars accumulate gradually over time and that sustained implementation is substantially more consequential than short-term or partial exposure. More broadly, the findings highlight the importance of evaluating school calendar reforms through a longitudinal lens, as short-run academic responses alone may provide an incomplete picture of their effects on longer-run educational trajectories.

The distribution of gains also highlights important policy and equity considerations. Although most student groups experience improvements in persistence and completion, the estimated gains are smaller and less consistent for English learners and homeless students, populations that rely more heavily on school-based structure and support services. These results indicate that alternative schedules may improve average outcomes while generating uneven effects across vulnerable populations if implemented without complementary supports. From a policy perspective, the findings underscore the importance of pairing schedule flexibility with targeted interventions, such as tutoring, language services, supervised programming, or additional academic supports on non-instructional days, in order to ensure that flexibility-enhancing reforms do not inadvertently widen existing educational disparities.

Evidence on mechanisms further helps explain why Colorado's experience differs from prior findings in other states. Unlike settings in which adoption of the 4DSW substantially reduces instructional time, Colorado's binding instructional-hour requirements largely preserve total classroom exposure. We therefore find little evidence that reductions in instructional time drive the effects observed in our setting. Instead, teacher retention emerges as a central organizational response. Districts adopting the 4DSW experience significantly higher teacher retention, increasing instructional continuity and workforce stability within schools. We also document modest increases in classroom-related expenditures, particularly instructional supplies, indicating some reinvestment in the learning environment following adoption. At the same time, we find limited evidence of large-scale expansion in purchased or community services that would indicate widespread enrichment programming on the non-instructional day. Finally, the organization of the schedule itself appears to matter: districts adopting a Monday-off structure experience more persistent gains in attainment than districts adopting a Friday-off schedule, highlighting that the effects of calendar reforms depend not only on whether instructional time is compressed, but also on how the school week is organized and implemented.

Taken together, the findings offer several broader lessons for education policy. First, alternative school calendars can improve high school persistence and completion when implemented under institutional conditions that preserve instructional time and support teacher stability. Second, the benefits of these reforms appear substantially more likely to emerge under sustained exposure rather than temporary adoption or partial implementation. Third, the effects of the 4DSW are not uniform across student populations, implying that policymakers should pay careful attention to the distributional consequences of schedule flexibility. More generally, the results demonstrate that the effects of calendar reforms are not inherent to the schedule itself, but depend fundamentally on the institutional environment in which the policy operates, including staffing responses, resource allocation, implementation quality, and organizational adaptation over time. As more states and school districts across the United States consider adopting alternative schedules in response to fiscal pressures, staffing constraints, and changing educational priorities, the evidence presented here provides new insight into the conditions under which the 4DSW can support student success and contribute to meaningful long-run gains in educational attainment and human capital formation.

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Table I. Summary Statistics: Student and Teacher Baseline Samples

	Four-Day Schools			Five-Day Schools
	All Time	Pre-4DSW	Post-4DSW	All Time
Panel A: Students				
Characteristics				
Male (%)	0.515	0.516	0.514	0.513
White (%)	0.532	0.546	0.520	0.580
Black (%)	0.018	0.019	0.015	0.059
Hispanic (%)	0.401	0.384	0.410	0.288
Asian (%)	0.015	0.017	0.011	0.035
English Learner (%)	0.095	0.096	0.092	0.100
Migrant Student (%)	0.013	0.015	0.017	0.004
Gifted Student (%)	0.036	0.035	0.038	0.055
Homeless Student (%)	0.019	0.021	0.014	0.014
Total Students	323,003	178,231	144,773	902,728
Academic Outcomes				
Test Taking Rate	0.832	0.840	0.825	0.851
English Test Score	17.42	17.30	17.60	18.99
Math Test Score	18.16	18.05	18.32	19.62
Grade Repetition (%)	0.148	0.156	0.135	0.135
Dropout (%)	0.121	0.140	0.109	0.118
On-Time Graduation (%)	0.720	0.716	0.736	0.747
Overall Graduation (%)	0.734	0.731	0.745	0.732
Panel B: Teachers				
Characteristics				
Male (%)	0.271	0.269	0.273	0.261
White (%)	0.928	0.929	0.926	0.922
Black (%)	0.002	0.002	0.002	0.004
Hispanic (%)	0.055	0.054	0.057	0.060
Asian (%)	0.002	0.002	0.002	0.006
Bachelor's Degree (%)	0.652	0.655	0.647	0.579
Master's Degree (%)	0.332	0.329	0.336	0.403
Years of Experience	9.74	9.72	9.77	9.13
Total Teachers	15,266	8,229	7,037	101,776
Labor Market Outcomes				
Retention (%)	0.755	0.750	0.760	0.743
Transfer (%)	0.061	0.062	0.059	0.053
Exit (%)	0.181	0.185	0.176	0.206

Notes: This table reports means for the baseline student and teacher samples. "Pre-4DSW" refers to cohorts or years before a district's adoption of the four-day school week, and "Post-4DSW" refers to cohorts following adoption. The five-day school column provides corresponding means for traditional districts.

Table II. Effect of 4DSW on High School Students' Academic Outcomes

	Participation	Achievement		Progression		Attainment	
	Taking Tests	**English Score**	**Math Score**	**Repetition**	**Dropout**	**Graduation**	**On-Time Graduation**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full Exposure	0.009	0.027**	0.025**	-0.001	-0.021*	0.032***	0.029***
	(0.010)	(0.009)	(0.007)	(0.004)	(0.011)	(0.011)	(0.011)
Partial Exposure	-0.002	0.006	0.002	-0.001	-0.010	0.013*	0.014***
	(0.009)	(0.009)	(0.007)	(0.004)	(0.009)	(0.007)	(0.011)
School Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Entry Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,224,731	720,489	720,473	1,224,731	1,224,731	1,224,731	1,224,731
Control Mean	0.851	0.006	0.006	0.135	0.118	0.747	0.732

Notes: This table reports difference-in-differences estimates of the impact of adopting 4DSW on high school student outcomes. Outcomes are grouped into four categories: *Participation* (an indicator for taking any standardized test during high school); *Achievement* (standardized ACT/SAT English and math scores); *Progression* (indicators for grade repetition in grades 9–12 and for dropout); and *Attainment* (graduation and on-time graduation). "Full exposure" refers to cohorts attending 4DSW schools continuously from grade 9 onward, while "partial exposure" refers to cohorts first exposed in grades 10–12. All specifications include school and entry-cohort fixed effects and the full set of controls. Robust standard errors, clustered at the school-district level, are reported in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table III. Effect of the Four-Day School Week on Student Outcomes by Timing and Duration of Exposure

	Taking Tests	**English Score**	**Math Score**	**Grade Repetition**	**Dropout**	**Graduation**	**On-Time Graduation**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Students Exposed Since Middle School							
4DSW Indicator	0.015	0.019*	0.023*	-0.006	-0.019**	0.043**	0.041**
	(0.013)	(0.016)	(0.010)	(0.010)	(0.006)	(0.008)	(0.009)
Panel B: Students First Exposed in High School							
4DSW Indicator	0.007	0.023*	0.026*	-0.001	-0.009	0.017**	0.016**
	(0.014)	(0.015)	(0.005)	(0.005)	(0.009)	(0.004)	(0.005)
Panel C: Incremental Effect of an Additional Year of Exposure							
4DSW (Years of Exposure)	0.003	0.004	0.003	-0.002	-0.004*	0.007***	0.006***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
School Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Entry Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,224,731	720,489	720,473	1,224,731	1,224,731	1,224,731	1,224,731

Notes: Each panel reports results from difference-in-differences specifications estimating the impact of the 4DSW on high school student outcomes. Panel A includes cohorts whose districts adopted the 4DSW while they were in middle school (grades 6–8). Panel B includes cohorts first exposed to the 4DSW upon entering ninth grade. Panel C estimates a specification relating outcomes to the cumulative number of years of exposure to the 4DSW, thereby capturing potential dose–response effects. All models include school and entry-cohort fixed effects and control for student demographics and baseline characteristics. Robust standard errors, clustered at the school district level, are shown in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table IV. Heterogeneous Effects of 4DSW on Student Outcomes by Subgroup

	Gender		**Race/Ethnicity**			**English Learner Status**		**Homeless Status**	
	Male	Female	White	Black	Hispanic	ESL	Non-ESL	Homeless	Non-Homeless
Panel A: Participation									
Test Taking	0.011	0.006	0.004	0.018	0.018	0.028	0.006	0.005	0.009
	(0.011)	(0.011)	(0.009)	(0.023)	(0.015)	(0.023)	(0.009)	(0.041)	(0.010)
Panel B: Achievement									
English (z)	0.045***	0.009	0.009	0.029	0.062**	-0.059	0.021*	-0.039	0.027**
	(0.014)	(0.018)	(0.018)	(0.054)	(0.028)	(0.044)	(0.013)	(0.064)	(0.014)
Math (z)	0.036**	0.014	0.009	0.010	0.007**	-0.093**	0.020*	-0.010	0.026**
	(0.015)	(0.014)	(0.018)	(0.088)	(0.031)	(0.039)	(0.012)	(0.064)	(0.012)
Panel C: Progression									
Grade Repetition	-0.010	-0.019	-0.008	0.003	0.000	0.034	-0.020	0.025	-0.015
	(0.014)	(0.013)	(0.007)	(0.017)	(0.019)	(0.022)	(0.011)	(0.062)	(0.013)
Dropout Rate	-0.025**	-0.016	-0.009	-0.028*	-0.017	0.001	-0.023**	0.015	-0.021*
	(0.013)	(0.011)	(0.007)	(0.018)	(0.013)	(0.018)	(0.011)	(0.027)	(0.012)
Panel D: Attainment									
Graduation Rate	0.042***	0.023*	0.026***	0.043	0.025**	-0.017	0.036***	-0.084	0.033***
	(0.011)	(0.013)	(0.008)	(0.039)	(0.013)	(0.034)	(0.010)	(0.083)	(0.011)
On-Time Graduation	0.036***	0.024*	0.024***	0.046	0.021	-0.028	0.026**	-0.121*	0.031***
	(0.011)	(0.013)	(0.008)	(0.033)	(0.013)	(0.034)	(0.034)	(0.076)	(0.011)
School Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Entry-Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	628,368	596,344	703,884	66,181	367,717	121,659	1,103,030	18,530	1,206,134

Notes: Each cell reports difference-in-differences estimates of the effect of adopting the four-day school week (4DSW) for the indicated subgroup. Robust standard errors clustered at the school-district level are shown in parentheses. Outcomes are grouped into *Participation* (test taking), *Achievement* (English and math test scores), *Progression* (course repetition and dropout), and *Attainment* (graduation and on-time graduation). All specifications include school and entry-cohort fixed effects and a full set of control variables.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table V. Effect of 4DSW on Teacher Outcomes

	Retention	**Transfer**	**Exit**
	(1)	(2)	(3)
4DSW	0.027***	0.002	-0.008
	(0.007)	(0.005)	(0.008)
School Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Controls	Yes	Yes	Yes
N	191,096	191,096	191,096
Control Mean	0.743	0.054	0.206

Notes: The table reports difference-in-differences estimates of the impact of 4DSW on high school teacher outcomes. The dependent variables are: an indicator for teachers retained at the same school (column 1), an indicator for teachers transferring to another school (column 2), and an indicator for teachers exiting the education sector (column 3). Robust standard errors are clustered at the school district level and shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

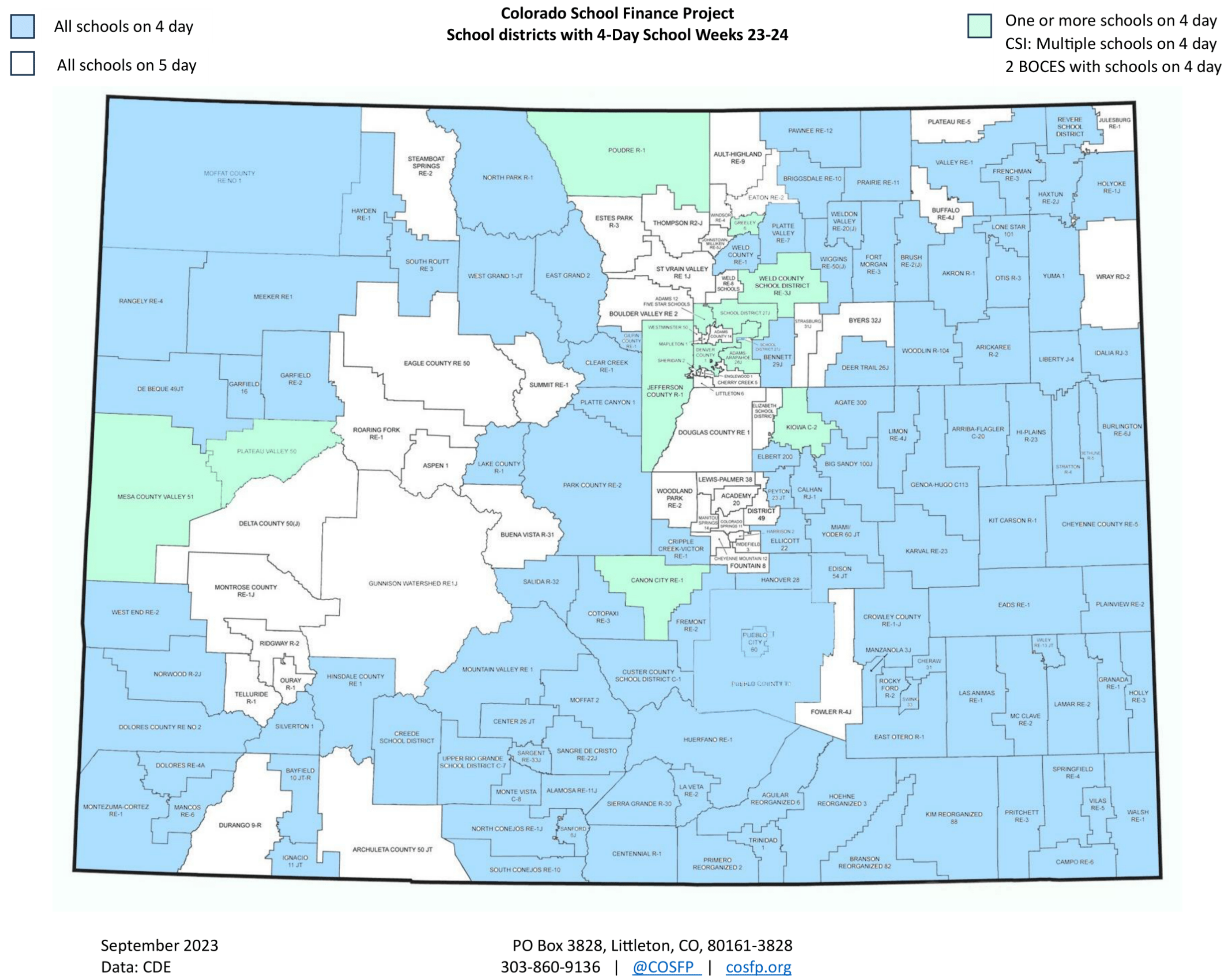

Figure 1. Map of 4DSW Districts in Colorado.

Notes: The figure shows the map of 4DSW districts in Colorado for the 2023–2024 academic year, as provided by the Colorado School Finance Project.

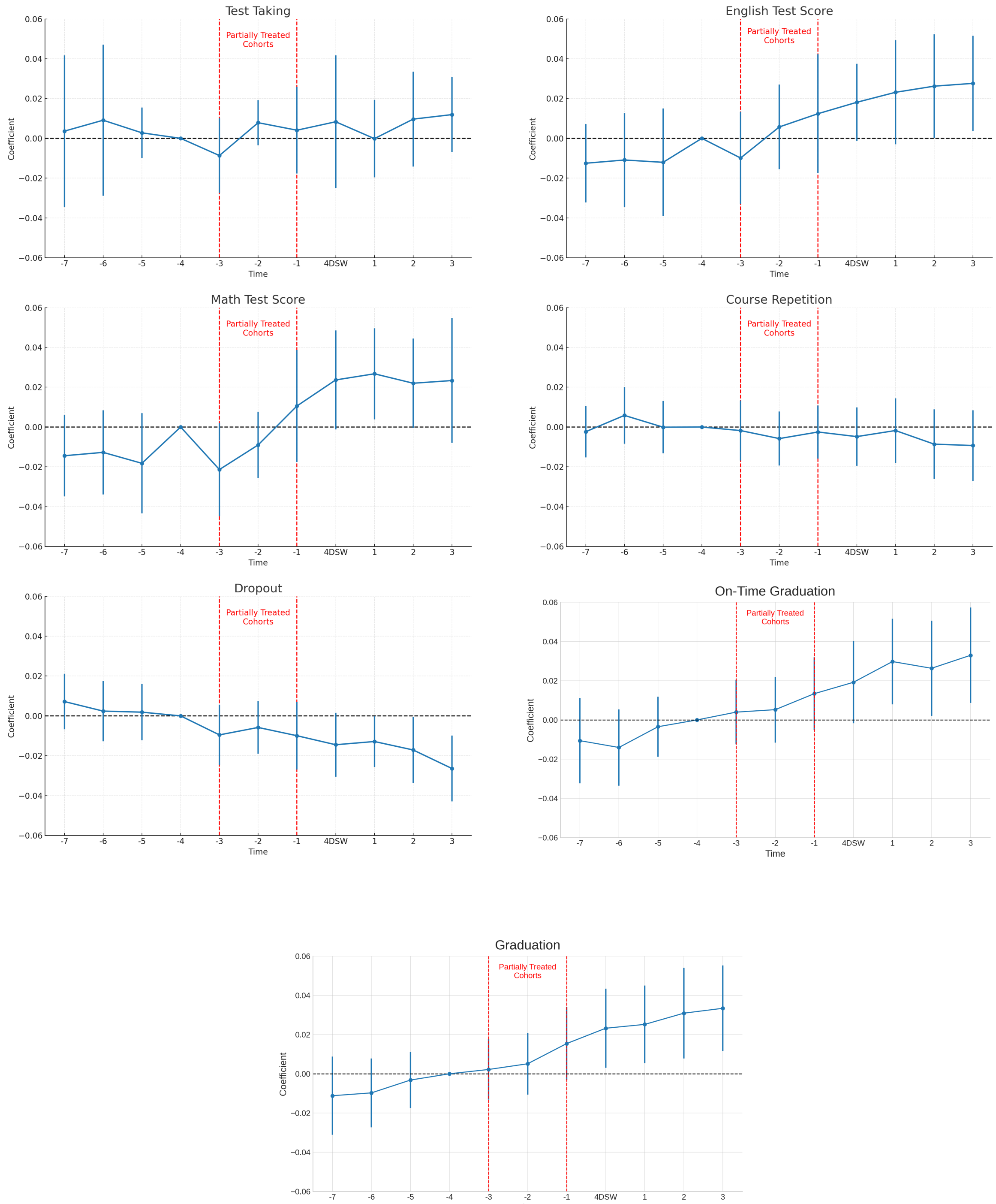

Figure 2. Event study of the effect of 4DSW on student outcomes.

Notes: The figure graphs the regression coefficient estimates and their 90% confidence intervals (vertical lines). Cohorts entered 9th grade 4 years before 4DSW implementation is the omitted category.

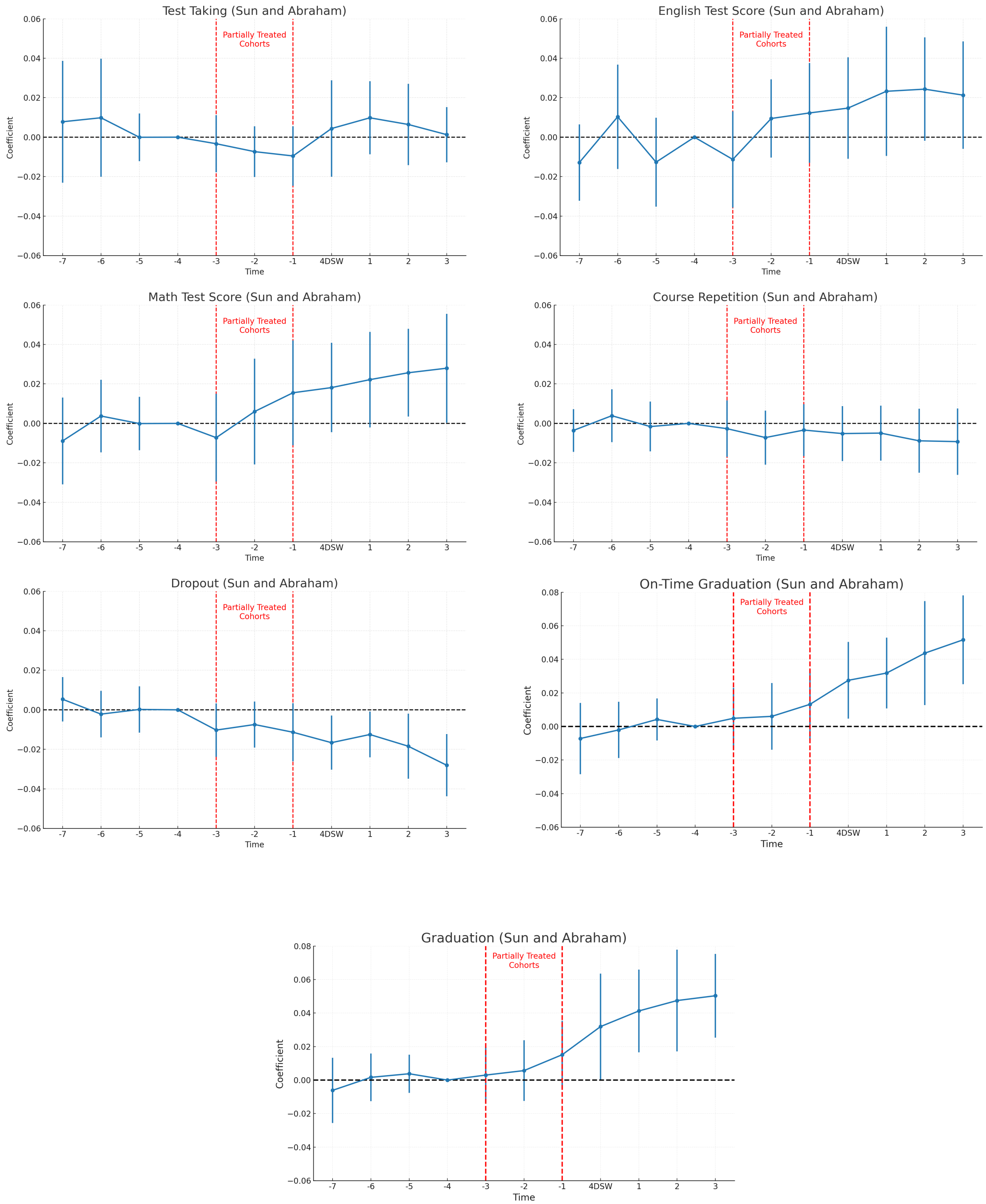

Figure 3. Event study of the effect of 4DSW on student outcomes: Sun and Abraham (2021).

Notes: The figure graphs the regression coefficients obtained by using interaction weighted estimator from Sun & Abraham (2021) and their 90% confidence intervals (vertical lines). Cohorts entered 9th grade 4 years before 4DSW implementation is the omitted category.

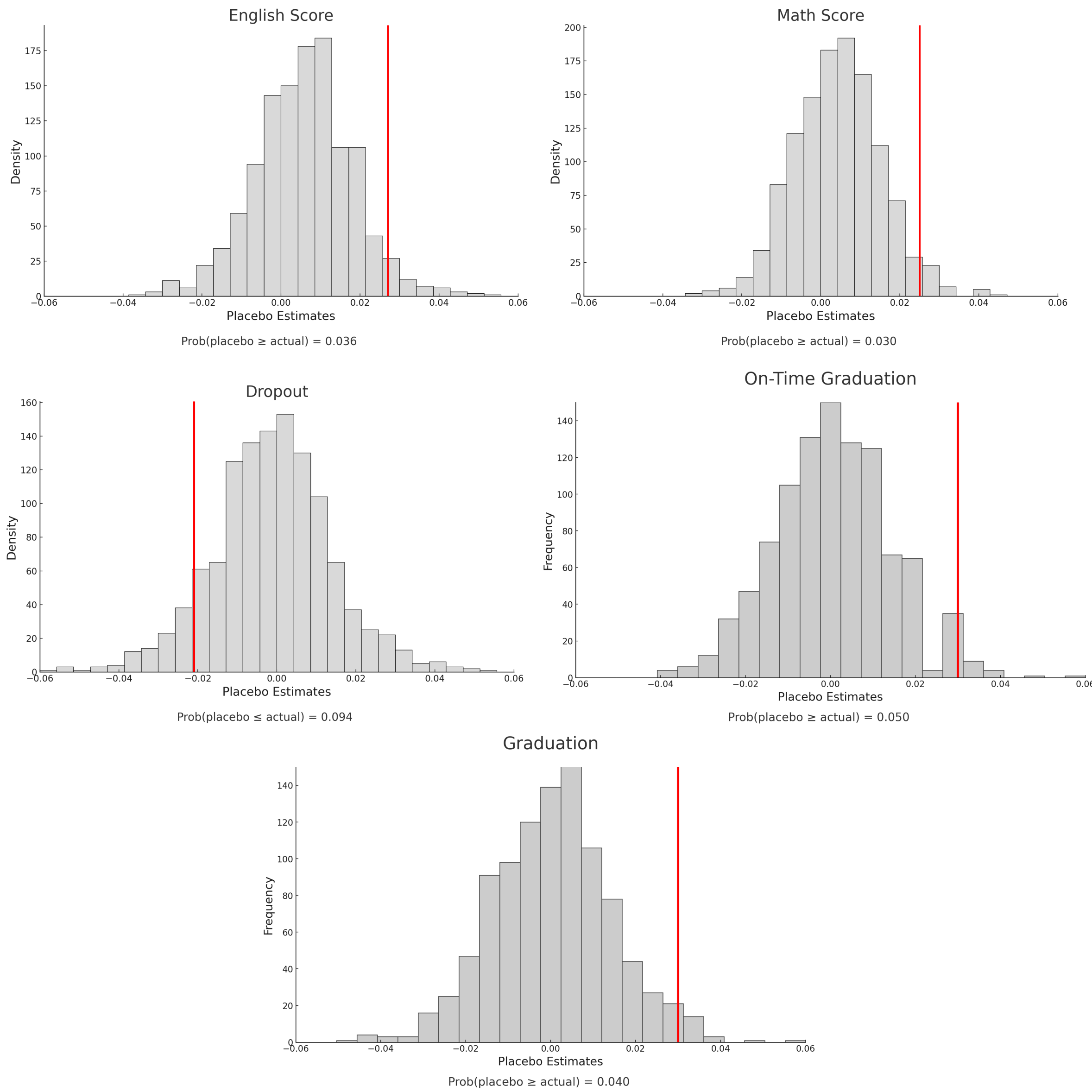

Figure 4. Placebo estimates.

Notes: The figure graphs the distribution of placebo coefficient estimates resulting from 1000 sets of random assignments of districts to 4DSW adoption. The red vertical lines represent the true estimates from Table 2.

Appendix Tables and Figures

Table A.1. Trends in Characteristics Before 4DSW Adoption and Predicting 4DSW Adoption Year

	Trend	**4DSW Adoption Year**
	(1)	(2)
Panel A: Student-level characteristics		
Total Enrollment	274.17	0.001
	(184.59)	(0.001)
Percent of Male Students	0.006	-0.012
	(0.005)	(0.022)
Percent of Minor Students	0.014	0.009
	(0.014)	(0.019)
Percent of ESL Students	0.001	-0.004
	(0.002)	(0.011)
Percent of Migrant Students	0.002	0.003
	(0.001)	(0.008)
Percent of Special Education	-0.001	0.003
	(0.002)	(0.006)
Percent of Gifted Students	-0.005	-0.008
	(0.009)	(0.025)
Percent of Homeless Students	0.001	-0.011
	(0.001)	(0.020)
Panel B: Teacher-level characteristics		
Total Teachers	8.39	-0.000
	(6.48)	(0.001)
Percent of Male Teachers	-0.017**	-0.014
	(0.009)	(0.028)
Percent of Minor Teachers	0.014	0.007
	(0.012)	(0.016)
% Teachers: High School Degree	0.002	-0.003
	(0.003)	(0.009)
% Teachers: Bachelor's Degree	0.019	0.005
	(0.014)	(0.012)
% Teachers: Master's Degree	-0.001	0.002
	(0.013)	(0.010)
N	3,674	119

Notes: Column (1) reports estimates of α_1 from equation (5). Each variable is obtained from a separate regression including district and year fixed effects; robust standard errors clustered at the district level are in parentheses. Column (2) tests whether the timing of 4DSW adoption is correlated with baseline (2005) district characteristics. Heteroskedasticity-robust standard errors are reported in parentheses for Column (2).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2. Estimations of 4DSW Entry Decisions by Districts

	English Score	**Math Score**	**Dropout**	**Graduation**	**Teacher Retention**	**Teacher Transfer**	**Teacher Exit**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2-Year Trend	0.001	-0.002	-0.008	0.002	0.005	-0.003	0.001
	(0.012)	(0.012)	(0.010)	(0.002)	(0.004)	(0.004)	(0.004)
3-Year Trend	0.007	0.006	-0.008	0.002	0.006	-0.004	0.001
	(0.011)	(0.013)	(0.009)	(0.002)	(0.004)	(0.004)	(0.004)
4-Year Trend	0.009	0.011	-0.009	0.002	0.007	-0.005	0.002
	(0.010)	(0.012)	(0.008)	(0.002)	(0.004)	(0.004)	(0.003)
Observations	115	115	115	115	115	115	115

Notes: This table reports estimates of whether the year of 4DSW implementation is correlated with outcomes prior to adoption. The "2-, 3-, and 4-Year Trends" correspond to the average student and teacher outcomes in the two, three, and four years preceding 4DSW adoption. Standard errors are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3. Student and Teacher Sorting Following 4DSW Implementation

Student Characteristic	**Student Sorting**	**Teacher Characteristic**	**Teacher Sorting**
	(1)		(2)
Total Enrollment	-272.80	Total Teachers	-7.53
	(170.89)		(6.57)
Percent of Male Students	-0.006	Percent of Male Teachers	0.024**
	(0.005)		(0.010)
Percent of Minor Students	-0.018	Percent of Minor Teachers	0.009
	(0.012)		(0.015)
Percent of ESL Students	-0.001	Percent of High School Degree	0.005
	(0.002)		(0.004)
Percent of Migrant Students	-0.001	Percent of Bachelor's Degree	-0.008
	(0.001)		(0.015)
Percent of Special Education	0.001	Percent of Master's Degree	-0.044
	(0.002)		(0.015)
Percent of Gifted Students	-0.005		
	(0.006)		
Percent of Homeless Students	-0.001		
	(0.001)		
District Fixed Effects	Yes	District Fixed Effects	Yes
Year Fixed Effects	Yes	Year Fixed Effects	Yes
N	3,674	Observations	3,674

Notes: The table reports how adoption of the 4DSW affects district-level student and teacher composition. Student characteristics and their sorting estimates are presented in the left two columns, while teacher characteristics and their sorting estimates are shown in the right two columns.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.4. Effects of 4DSW on Student Attrition and Switching

	Attrition (Entry)	**Attrition (Exit)**	**Switching Schools**
	(1)	(2)	(3)
4DSW	-0.001	0.001	-0.013
	(0.002)	(0.002)	(0.012)
School Fixed Effects	Yes	Yes	Yes
Entry Cohort Fixed Effects	Yes	Yes	Yes
N	1,224,731	1,224,731	1,224,731

Notes: This table reports estimated effects of 4DSW adoption on student attrition and school switching. *Attrition (Entry)* equals one if a student is observed in any grade but does not appear in any Colorado public high school in ninth grade, capturing attrition prior to high-school entry. *Attrition (Exit)* equals one if a student is observed in ninth grade but never reappears in grades ten through twelve and is not classified as a dropout or graduate, capturing attrition after entering high school. *Switching Schools* equals one if a student changes schools at any point. All specifications include school and entry-cohort fixed effects. Robust standard errors, clustered at the district level, are reported in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.5. Effect of 4DSW on High School Students' Academic Outcomes: Robustness Checks

	Taking Tests	English Score	Math Score	Grade Repetition	Dropout	Graduation	On-Time Graduation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Propensity Score Matching							
4DSW	0.003	0.015	0.015*	-0.026*	-0.027**	0.030***	0.032***
	(0.011)	(0.012)	(0.006)	(0.013)	(0.010)	(0.011)	(0.009)
N	616,684	377,922	377,922	616,684	616,684	616,684	616,684
Panel B: Random Forest Classifier							
4DSW	0.006	0.026*	0.023**	-0.016	-0.020*	0.026**	0.028***
	(0.010)	(0.014)	(0.012)	(0.013)	(0.011)	(0.010)	(0.009)
N	834,106	500,994	500,944	834,106	834,106	834,106	834,106
Panel C: Inverse Probability Matching							
4DSW	0.003	0.014	0.013*	-0.018	-0.018*	0.022**	0.024***
	(0.010)	(0.012)	(0.009)	(0.012)	(0.010)	(0.010)	(0.009)
N	1,224,731	720,473	720,473	1,224,731	1,224,731	1,224,731	1,224,731
Panel D: Excluding Control Variables							
4DSW	0.008	0.027*	0.025*	-0.001	-0.0212*	0.032***	0.029***
	(0.008)	(0.012)	(0.011)	(0.008)	(0.011)	(0.010)	(0.010)
N	1,224,731	720,473	720,473	1,224,731	1,224,731	1,224,731	1,224,731
Panel E: District Specific Linear Pre-trend							
4DSW	0.007	0.020*	0.021*	-0.008	-0.023*	0.025**	0.027**
	(0.013)	(0.011)	(0.010)	(0.006)	(0.012)	(0.011)	(0.012)
N	1,224,731	720,473	720,473	1,224,731	1,224,731	1,224,731	1,224,731
School Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Entry Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each panel reports difference-in-differences estimates of the effect of 4DSW adoption on high school students' academic outcomes under alternative specifications. Panel A matches treated and control schools using propensity score matching. Panel B applies a random forest classifier to construct matched comparison groups. Panel C uses inverse probability matching to reweight comparison units. Panel D re-estimates the baseline model without any controls. Panel E incorporates district-specific linear pre-trends following Goodman-Bacon (2021). Robust standard errors clustered at the school district level are in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.6. Effect of 4DSW on High School Students' Academic Outcomes: Additional Estimates

	Taking Tests	**English Score**	**Math Score**	**Grade Repetition**	**Dropout**	**Graduation**	**On-Time Graduation**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Excluding Partially Treated Cohorts							
4DSW	0.009	0.030**	0.028**	-0.015*	-0.020*	0.031**	0.032**
	(0.011)	(0.013)	(0.012)	(0.013)	(0.011)	(0.011)	(0.009)
N	1,182,640	1,182,640	1,182,640	1,182,640	1,182,640	1,182,640	1,182,640
Panel B: Pre-COVID Sample							
4DSW	0.017	0.023*	0.026*	-0.002	-0.014	0.030***	0.028***
	(0.010)	(0.014)	(0.015)	(0.008)	(0.013)	(0.011)	(0.011)
N	810,857	538,175	538,175	810,857	810,857	810,857	810,857
Panel C: Excluding BOCES and Charter Schools							
4DSW	0.009	0.023*	0.019*	-0.002	-0.021*	0.033**	0.031***
	(0.010)	(0.013)	(0.011)	(0.009)	(0.011)	(0.011)	(0.011)
N	1,194,796	704,181	704,181	1,194,796	1,194,796	1,194,796	1,194,796
Panel D: Rural/Small Districts Only							
4DSW	-0.001	0.024*	0.016	-0.013	-0.019**	0.034***	0.035***
	(0.010)	(0.014)	(0.013)	(0.010)	(0.008)	(0.009)	(0.009)
N	268,900	155,110	155,110	268,900	268,900	268,900	268,900
School Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Entry Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Panel A excludes cohorts partially exposed at baseline (i.e., students already in grades 10–12 at policy start). Panel B restricts to cohorts graduating prior to the COVID-19 pandemic. Panel C drops BOCES (Boards of Cooperative Educational Services) and charter schools. Panel D restricts to rural/small districts. All specifications include school and entry-cohort fixed effects and a set of covariates. Robust standard errors, clustered at the school district level, are shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.7. Effect of 4DSW on Test Scores: ACT- and SAT-Based Cohorts

	ACT-Based Cohorts	**SAT-Based Cohorts**
	(1)	(2)
English Score	0.021*	0.028*
	(0.012)	(0.017)
Math Score	0.027*	0.026*
	(0.015)	(0.014)
School Fixed Effects	Yes	Yes
Entry Cohort Fixed Effects	Yes	Yes
N	419,636	300,455
Controls	Yes	Yes

Notes: This table reports estimates of the effect of 4DSW on standardized test outcomes, separately for ACT-based and SAT-based student cohorts. Standardized scores are normalized within each assessment. Robust standard errors clustered at the school district level are shown in parentheses.
* $p < 0.10$, $^{*}*$ $p < 0.05$, $^{*}**$ $p < 0.01$

Table A.8. Effect of 4DSW on Teacher Outcomes (All)

	Retention (1)	**Transfer** (2)	**Turnover** (3)
4DSW	0.019*	0.001	-0.007
	(0.010)	(0.004)	(0.007)
School Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Controls	Yes	Yes	Yes
N	667,533	667,533	667,533
Control Mean	0.751	0.053	0.199

Notes: The table reports estimates of the impact of 4DSW on teacher outcomes (1st grade to 12th grade). The dependent variables are: an indicator for teachers retained at the same school (column 1), an indicator for teachers transferring to another school (column 2), and an indicator for teachers exiting the education sector (column 3). Robust standard errors are clustered at the school district level and shown in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.9. Effect of 4DSW on District Annual Instructional Hours

	Annual Instructional Hours
	(1)
4DSW	23.64
	(27.08)
District Fixed Effects	Yes
Year Fixed Effects	Yes
N	3,592
Controls	Yes

Notes: This table reports estimates of the effect of 4DSW on annual instructional hours. The dependent variable is total district-level annual instructional hours. Robust standard errors are clustered at the school district level and shown in parentheses.
* $p < 0.10$, $^{*}*$ $p < 0.05$, $^{*}**$ $p < 0.01$

Table A.10. Effect of 4DSW on Student Outcomes by Day Off

	Taking Tests	English Score	Math Score	Grade Repetition	Dropout	Graduation	On-Time Graduation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Schools with Friday Off							
4DSW	0.005	0.021	0.020*	0.017*	-0.12	0.012	0.006
	(0.009)	(0.013)	(0.011)	(0.010)	(0.012)	(0.015)	(0.015)
Panel B: Schools with Monday Off							
4DSW	0.006	0.021	0.020*	-0.002	-0.012	0.025**	0.024**
	(0.009)	(0.013)	(0.011)	(0.009)	(0.013)	(0.010)	(0.010)
School Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Entry Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,224,731	720,473	720,473	1,224,731	1,224,731	1,224,731	1,224,731
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes:This table reports the estimates of the effect of adopting the four-day school week (4DSW) on student outcomes, distinguishing between schools that take Friday off (Panel A) and those that take Monday off (Panel B). Robust standard errors are clustered at the school-district level and shown in parentheses. The coefficient estimates for graduation and on-time graduation are statistically different across the two schedule types ($p < 0.05$).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.11. Effect of 4DSW on Teacher Salaries and Benefits

	Teacher Salaries	**Teacher Benefits**
	(1)	(2)
4DSW	-0.003	-0.002
	(0.040)	(0.054)
District Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
N	1,636	1,636
Controls	Yes	Yes

Notes: This table reports estimates of the effect of 4DSW adoption on the log of teacher salaries and benefits. Robust standard errors clustered at the district level are shown in parentheses.
* $p < 0.10$, $^{*}*$ $p < 0.05$, $^{*}**$ $p < 0.01$

Table A.12. Effect of 4DSW on District Expenditures: Instructional and Supplies Categories

	Instructional Expenditures	**Supplies Expenditures**
	(1)	(2)
4DSW	0.008	0.183**
	(0.018)	(0.095)
District Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
N	1,636	1,636
Controls	Yes	Yes

Notes: This table reports estimates of the effect of 4DSW adoption on the log of district expenditure outcomes. Instructional expenditures include classroom-related costs directly tied to teaching. Supplies expenditures capture spending on textbooks, consumables, technology, and other classroom materials. Robust standard errors clustered at the district level are shown in parentheses.
* $p < 0.10$, $^{*}*$ $p < 0.05$, $^{*}**$ $p < 0.01$

Table A.13. Effect of 4DSW on District Expenditures: Purchased and Community Services

	Purchased Services	**Community Services**
	(1)	(2)
4DSW	-0.117	-0.131
	(0.088)	(0.104)
District Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
N	1,636	1,636
Controls	Yes	Yes

Notes: This table reports estimates of the effect of 4DSW adoption on the log of district expenditure outcomes. Purchased services include payments to external providers of educational or extracurricular programs, while community services encompass spending on student and family engagement outside of regular instruction. Robust standard errors clustered at the district level are shown in parentheses.

* $p < 0.10$, $^{*}*$ $p < 0.05$, $^{*}**$ $p < 0.01$

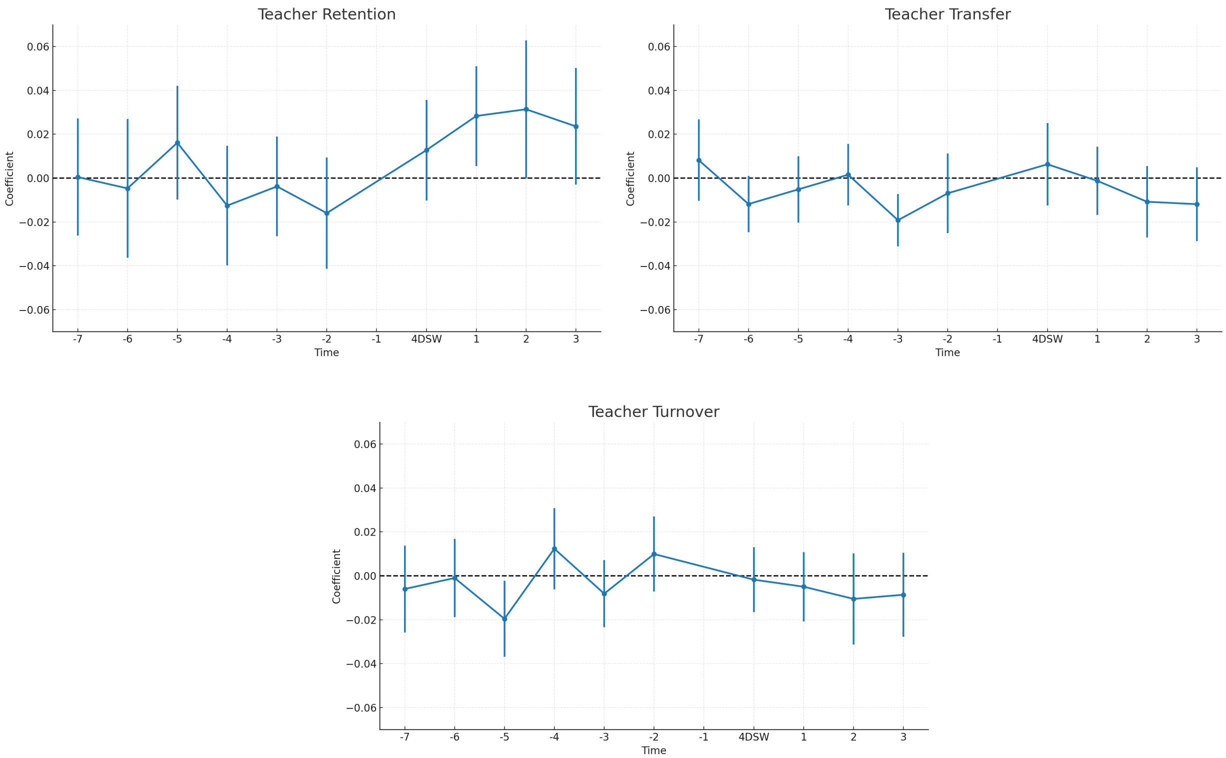

Figure A.1. Event study of the effect of 4DSW on teacher outcomes.

Notes: The figure graphs the regression coefficient estimates and their 90% confidence intervals (vertical lines). Year prior to 4DSW implementation is the omitted category.

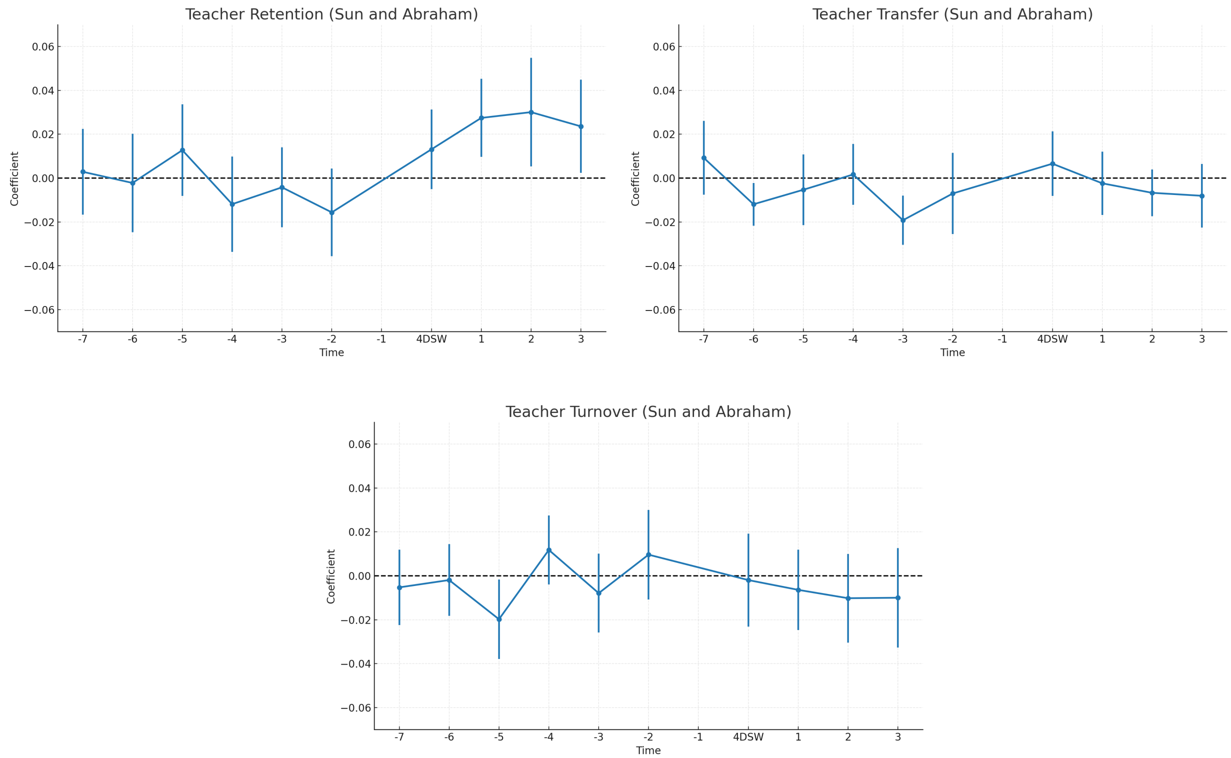

Figure A.2. Event study of the effect of 4DSW on teacher outcomes: Sun and Abraham (2021).
Notes: The figure graphs the regression coefficients obtained by using interaction weighted estimator from Sun & Abraham (2021) and their 90% confidence intervals (vertical lines). Year prior to 4DSW implementation is the omitted category.

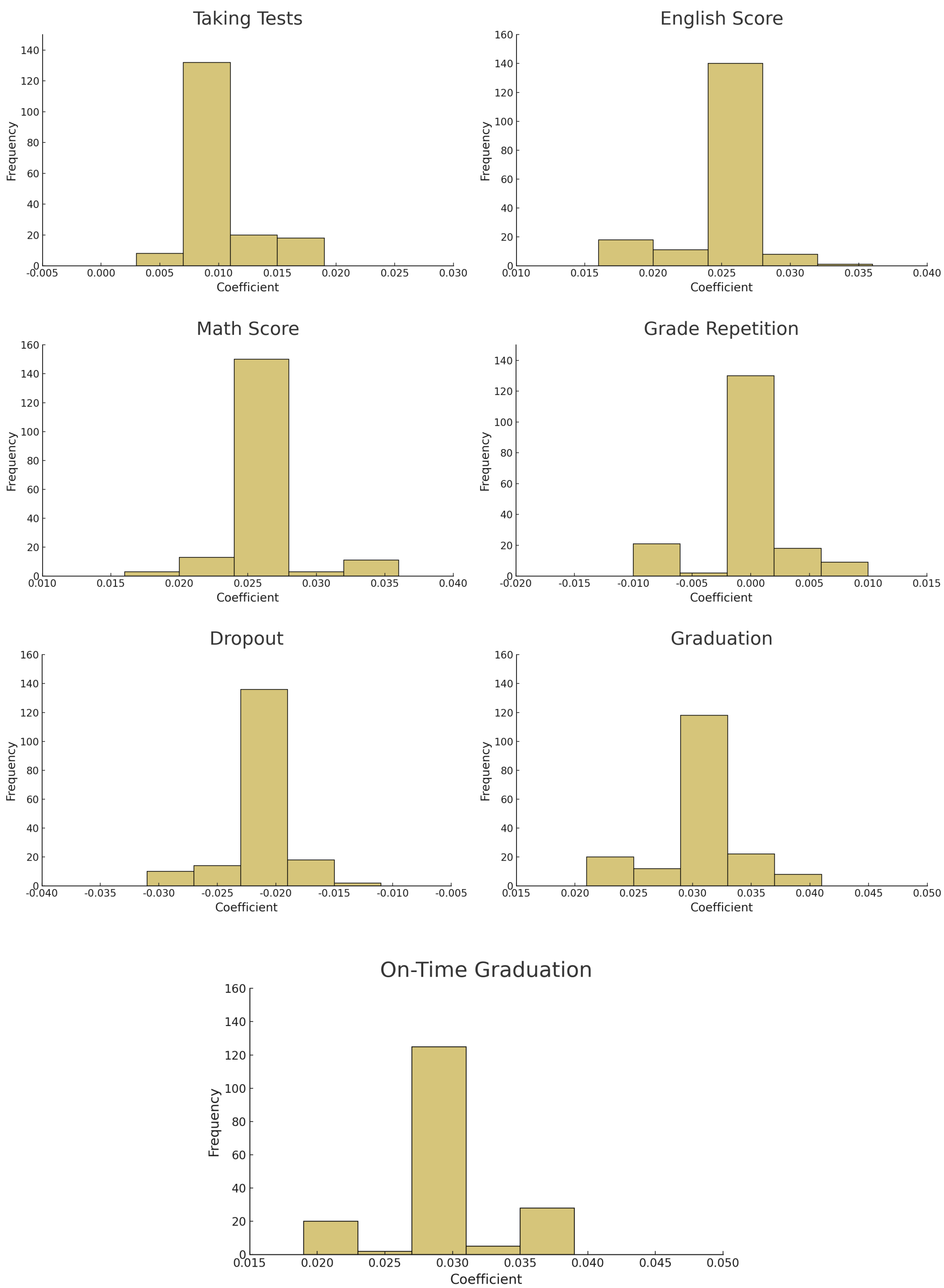

Figure A.3. Leave-one-district out estimations.

Notes: This figure shows the distribution of the leave-one-district-out coefficient estimates of 4DSW on student outcomes. The baseline specification for student outcomes is estimated repeatedly, each time removing a different school district.

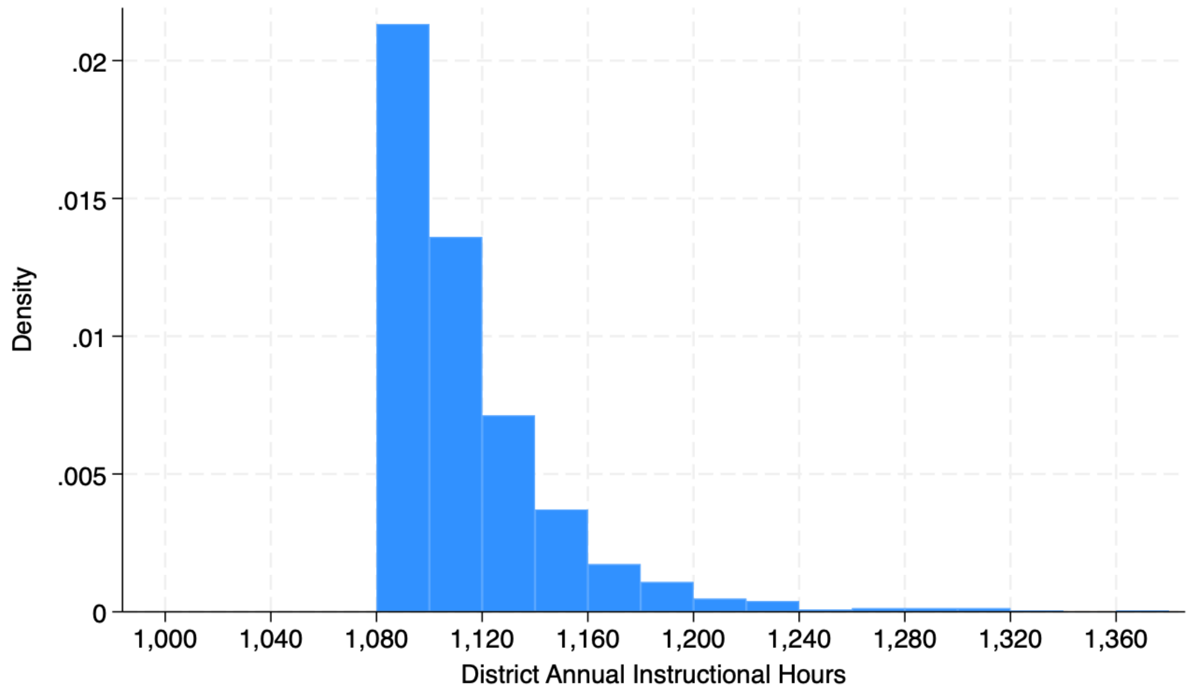

Figure A.4. Histogram of annual instructional hours.

Notes: This figure shows the distribution of school districts' annual instructional hours. In Colorado, public schools are required to provide a minimum of 1,080 instructional hours per year.